The Solar System Scale Model
User Guide

Background information and tips to use the Planet Path

CONTENTS

Introduction

Help
Fortunately, in the creation of both sets of the Solar System Model, I had a lot of help from some people who read the texts critically and pointed out mistakes, errors and ambiguities. These are (in alphabetical order):
Owen Gay, Cor de Graaf, Jean-Pierre Grootaerd, Wendy Hamilton (of Curious Minds), Vera Korte, Ralph Snel, Ad Stolk and especially my Marja. Thanks in part to them, this has become a beautiful and educational product.

Reading Tips
In this manual I use the system of referencing that I also use in my books.
The purpose is not to explain something everywhere, but in just one place, in that case printed in ***bold****. If the same term is mentioned elsewhere, it is* ***italicized*** *there. You then know that it is explained elsewhere and where that is you will find in the* ***Index*** *at the back.*
However, there are also words that are in italics but not because of the above. This concerns matters that have to do with language, such as in the explanation of perihelion and aphelion on page 11. References are also printed in italics.

Right*: for the cover pages of both sets we took pictures in a park in Amersfoort. For that purpose I had come up with a cheap way to set up the cards: sticks on which pegs are glued. Photo Rene van Melzen.*

Your Own Planet Path

Understanding distances in the solar system
The solar system is huge, with distances of millions and billions of kilometers. Those numbers, important as they may be, don't really tell us much. No one can really imagine the distance of 4.5 billion km to Neptune.
You can give an overview of the distances and dimensions with the help of illustrations, as I do in my books, but then you can compare either the dimensions of the 'members' of the **Solar System objects**, or their distances to the Sun. Never both, because in a picture in a book with the distances to scale, the planets and smaller objects - and even the Sun - are too small to see! To get a really good understanding you need a scale model. And the space to set up that scale model. Doing so will give you a *Planet Path*!
It is great fun to set up the Planet Path and then study it, especially with children, at school, in a park or on the street, or at home. If you have the children place or hang the cards at the correct distances (see *Setting up your Planet Path*, p. 13) they are alkso learning about measuring!
This is the User Guide for the Solar System Scale Model. It contains background information and tips. If you are missing answers in this manual or if you have other comments or remarks, please send them to **info@walrecht.nl**. I can then improve or supplement the manual if necessary.

Scale of 1:100 billion
In a scale model on a scale of 1:100 billion, all objects and their distances from the Sun have been reduced 100 billion times: 1 cm therefore represents a million km in real life! Do the math: 1 cm in the scale model = 100 billion cm in reality, or a billion meters = a million km. That means that the distance from the Sun to Neptune (the eighth and farthest planet) in this model is 45 m. *Dwarf planet* Pluto is now more than 50 m from the sun.
When I say 'to scale' in this user manual I mean the scale of 1:100 billion!
A Planet Path is normally set up in a straight line. This is the easiest and best reflects the differences in distance. In reality, the situation where all the planets are aligned will never occur, let alone a situation where all smaller objects are also aligned. All members of the Solar System have their own orbit around the Sun, and can be in all directions from the Sun.

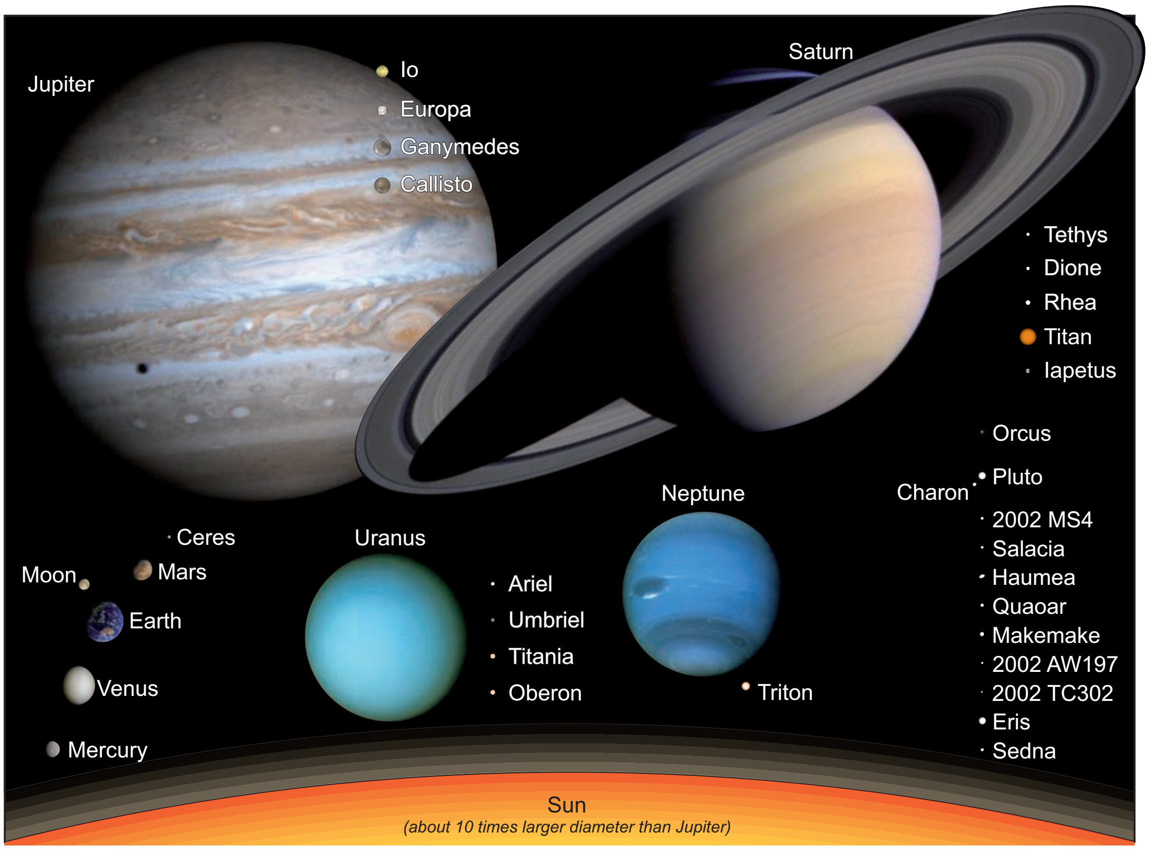
Converting distances
The advantage of a metric scale, such as 1:100 billion, is that you can easily convert distances and dimensions. The Earth is at almost 150 million km: 150 cm in the model. Neptune is 4500 million km from the sun: 45 m in the model.
The distances to new objects or objects that are not included in the Solar System Scale Model can be quickly converted to their place in the model. Suppose a new, large *KBO* (see *Reading Tips*, in the left column) is discovered 8 billion km from the sun. You can then convert that on the basis of '1 cm for 1 million km': 80 m. Or you can take a shortcut: as Neptune's scale distance is 45 m, and its real distances is 4,5 billion km, it's quick to realise this new object at 8 billion km must be at 80 m in the scale model! The more experience you have with distances to scale, the faster you can make such calculations.

Set-up

The old scale model
Our first Solar System model, released in 2003, contained cards for the Sun, the (then) nine planets, the Moon, the Voyager space probes, comets, and an 'And beyond…' card. This last card provides information about nearby stars, with dimensions and distances on the same scale. There was also a card for Quaoar, a then newly discovered KBO. It was the first major *Kuiper Belt Object* discovered since Pluto, in 1930.
However, many more such large *ice dwarfs* have been discovered since 2003, including many by astronomer Mike Brown and his team. Brown is an expert on the outer reaches of the Solar System and I based my information of the sizes and distances of ice dwarfs on his list (see *http://web.gps.caltech.edu/~mbrown/dps.html*) .
Furthermore, the Solar System beyond Neptune has been categorised according to the orbits of its inhabitants, these ice dwarfs. For example, the *Kuiper Belt* was further divided into groups with similar orbits and we have designated areas with objects that reside even further from the Sun.

The new set-up
As a result of all these new developments, the old Solar System scale model was not only outdated, but sixteen cards had become too little to get a good picture of what we now know about our 'neighbourhood'. So the new Dutch scale model was made up of two sets: a **basic set** with the most important Solar System objects and a **supplement set** with sixteen more interesting objects and regions in the Solar System. In the English version these sets are combined into a basic set of 32 cards (MDL-SS1).

Making choices
A lot of thought was required when composing the supplement set: which objects do really add something to the model? I myself had been using specially designed extra cards for my own Planet Path for years during lessons and lectures. These were then also free to download on our website. We still design new cards when for interesting enough objects, and put them for download on our site.
I used the extra cards, for example, to properly define the *Asteroid Belt* (Vesta is on the inside of that belt, Hermione on the outside). I also used one *centaur*, Chariklo, to describe that group of chased away ice dwarfs. Comets are of course important (the distances are for Halley's comet) and the two Voyagers space probes nicely show what humans are capable of: both have already left the Solar System!
In addition, I particularly wanted to have cards for the distinguishable regions in the Solar System in the supplement set. In addition to the aforementioned Asteroid Belt and Kuiper Belt, these are the *Oort Cloud* and the *Scattered Disc* (we describe all of those below).



Enjoying the Solar System
The illustrations in this brochure are mainly from my Dutch book 'Genieten van het zonnestelsel' ('Enjoying the Solar System'). That book contains a lot of information, photos and illustrations about the Sun, the planets and all other solar system objects. It tells about the origin and evolution, about processes that produced the worlds as we see today and much more.
It is highly recommended (for Dutch speakers) if you want to be able to use the Solar System Scale Model optimally, because I could never provide so much information on the cards and in this brochure.
Unfortunately, I have not found a publisher, yet, for English versions of this and my other books and products.

English supplement
Both Dutch sets contain 32 cards, which in the English version are combined into one basic set (MDL-SS1). But of course there are many more interesting objects. Therefore, we published an English supplement set with still more interesting and fun objects and area's: set MDL-SS2.

Extra cards
When there are more objects interesting enough to include in the scale model, new cards can be downloaded via: *https://www.walrecht.nl/en/about-our-products/about-the-solar-system-scale-model/new-information-and-additions.*

Left*: a 'familiy portrait' of the Solar System. It shows all objects with a diameter of 600 km and larger. The Sun is only shown for a small partially because on this scale it is 63 cm in diameter!*
After the Sun and the eight planets, the seven largest moons (or natural ***satellites****) are the largest objects in the Solar System. Dwarf planets like Pluto and Eris are smaller.*

Introduction

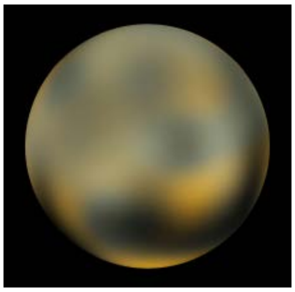
Too many planets!

On January 1, 1801, Ceres was discovered, quickly followed by other new 'planets', such as Pallas and Vesta.
By 1865, there were already one hundred new planets and people started to wonder whether we should not put them in a class of their own. That became the class of the ***asteroids****. No one had a problem with that, by the way…*

Composition

In the early Solar System, and indeed in the entire Universe, certain substances were in abundance. Mainly there were the gases hydrogen and helium, as well as molecules that are made up of oxygen, nitrogen and carbon. Water consists of hydrogen and oxygen, carbon monoxide and carbon dioxide of carbon and oxygen, methane ('natural gas') of carbon and hydrogen, ammonia of nitrogen and hydrogen.
Other common, but far less abundant elements are silicon, sulfur, iron, and magnesium. Silicon and oxygen form the basis for minerals ('rocks'): silicates. It is obvious that the molecules made up of the most common atoms were also the most common.
However, molecular hydrogen (made up of two hydrogen atoms) and helium dominated the ***presolar nebula*** *(see page 5, right column). Most of the hydrogen and helium went into the Sun, which consists of 84% hydrogen and 16% helium. The Sun 'burns' hydrogen in its core (****nuclear fusion****).*

Below*: the best image we had of Pluto until right before the passage of the space probe New Horizons, on 14 July 2015, was this one by the Hubble Space Telescope.*
Midden*: Pluto, as imaged by New Horizons.*
Rechtsonder*: Pluto's moon Charon, also imaged on 14 July 2015.*



Final selection

Then there were still six more cards to fill. It took me quite some time to make the final selection. Should I just take the largest objects? Or should I focus on objects that really add something to the scale model? I chose the latter: objects that serve as examples of objects with different orbits in the Kuiper Belt (Quaoar and Orcus); objects that define an area (Salacia neatly indicates the inside of the Kuiper Belt and 2002 AW197 the outside); and objects that are very far away, and represent other groups of *TNO's* (2007 OR10 and Sedna).
I am very satisfied with the composition of the English basic set. However, there were still more interesting and fun objects and area's that deserved attention. Which is why in 2020 a set of 24 cards was published for the Dutch and the English models. New discoveries and insight may lead to extra (downloadable) cards.

Pluto

In 2006, Pluto was 'demoted' from the position as the ninth (and by far the smalles) planet, to become a member of the new class of *dwarf planet*s. There has been a lot of discussion about that, especially in the US, where even astronomers are very emotional about this degradation. Incidentally, Pluto itself is of course still the same, wonderful ice world it was before. What is the problem?
After its discovery in 1930 Pluto was overestimated to be as large as the Earth. its diameter was later found to be about two-thirds that of our Moon in 1978! In addition, Pluto has an elongated orbit with a large *orbital inclination* (17°), and we have known for some time that Pluto and Neptune are in a 2:3 *orbital resonance*, due to the gravity of the large planet. All in all, it became increasingly difficult to maintain that Pluto belonged to the class of planets! Perhaps it was better to call it a large *asteroid*. Incidentally, Pluto's moon Charon is very large in relation to Pluto, and some call the Pluto/Charon system a **double dwarf planet**.

No longer a planet

But for a long time Pluto was the only one of its kind: a fairly large ice world orbiting the Sun. That was… until the discovery of the object we now call Eris was announced in 2005. This object is even further away from the Sun, has an even greater orbital inclination, and was then thought to be larger than Pluto. A tenth planet? But if more of those large objects were found (which indeed happened)? Then we would get a lot of planets! We had experienced something similar in the 19th century (see *Too many planets*, in the left column).

Definitions

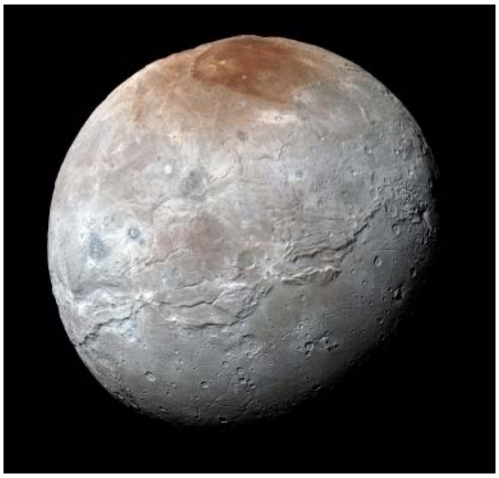
After some turbulent meetings, the International Astronomical Union (IAU) decided in August 2006 that a new class of **dwarf planets** should be created. Pluto, Eris and Ceres were the first, followed in the fall of 2008 by Makemake and Haumea. The asteroid 10 Hygiea may also be one.
What is a planet and what is a dwarf planet? A **planet** is now defined as an object that:

1. Orbits the Sun.
2. Has sufficient mass to have become spherical by its own gravity (called **hydrostatic equilibrium**).
3. Dominates its orbit (see below), so doesn't allow other large objects there.

A dwarf planet satisfies only the first two conditions but not the third.

Domination

What does that mean: to *dominate its orbit*? It means that no other large objects are orbiting atthe same distance to the Sun. We are not talking about moons, because these orbit a (dwarf) planet and are therefore dominated by definition. Smaller objects may in certain cases be 'tolerated' in the same orbit (see *Lagrange points*, on page 6).



Structure and formation of the Solar System

Inner and outer Solar System
We can divide the Solar System into the Inner Solar System, with the rocky planets Mercury, Venus, Earth and Mars (in terms of composition we could include the Moon), and the Outer Solar System, with the giant planets Jupiter, Saturn, Uranus and Neptune. However, outside the realm of the giants are many more objects.
The **rocky planets** are the smallest planets but have a higher **average density**: the mass per volume (in grams per cm^3 or kg per liter). Very briefly: metals have a higher density, the density of silicates (common minerals, rocks) is lower, that of water is 1 and that of gases is less than 1 (see right column). Although the giant planets are much larger, they have a lower density, so less mass per volume.
The dividing line between the Inner and Outer Solar System is the **frost line**, the distance from the Sun at which in the early Solar System substances such as water, ammonia, methane could condense. Astronomers call these substances **ices**, because at those distances from the Sun they only exist as ice.

Formation of the planets
Then the differences in density also become clear. In the red-hot protoplanetary disc (see right column), the disc of gas and dust from which the Solar System arose, everything was in gaseous form. Only when the material could **condense** (solidify) could the formation of the planets begin. The frost line was decisive:

- Within the frost line it was so hot that only metals and silicates could condense there. That's why the rocky planets and the Moon are made up mainly of metals (iron and nickel in the core) and silicates (in the mantle and crust).
- Beyond the frost line, the ices could condense. Hydrogen and helium, which make up the Sun (84% hydrogen and 16% helium), were unable to condense anywhere (they only do so at -253°C and -272°C, respectively).
- For example, Jupiter and Saturn in particular were able to grow because of all the ice that was there. When Jupiter and Saturn were heavy enough (about ten times the mass of the Earth), they could also swallow hydrogen and helium, so we can call these planets **gas giants**.
- Because of their greater distance, Uranus and Neptune had to make do with what Jupiter and Saturn had left for them: their big 'brothers' had already absorbed all the gas. Uranus and Neptune have therefore remained smaller and contain mostly ice and few gases. That is why I personally use the name **ice giants** for these two planets, although many call them gas giants (a wrong name as far as I'm concerned).

The region of the four giant planets is delineated by Jupiter, whose enormous gravity holds the objects in the *Asteroid Belt* in place, and Neptune, which similarly 'rules' the *Kuiper Belt*. Both giants determine where small objects are allowed to orbit. They also cause some orbits to remain empty.

The small worlds
The smaller Solar System objects, such as asteroids and ice dwarfs (in English 'minor planets') also move in more or less defined areas around the Sun. After the planets, if you consider sizes and masses, first come the seven major *satellites*, or *moons*: our Moon, Jupiter's four major moons (Io, Europa, Ganymede and Callisto), Titan (Saturn) and Triton (Neptune). Only some distance after these seven come the dwarf planets Pluto and Eris.

The Asteroid Belt
We find the *asteroids* around the frost line, in a circular area with the shape of an inner tube of a car wheel (cars used to have these...), or a donut: to scale it is 2.35 m deep (from 3.15 to 5.5 m from the Sun) and about 1.5 m thick. We call such a donut-shaped disk around a star a **belt**. See the drawing at the bottom left of the next page.

The Kuiper Belt
Beyond Neptune we find another belt, which we call the *Kuiper Belt*. In the scale model we find it from 45 m (the distance Sun-Neptune) to about 82 m. It is also very thick: more than 20 meters! The Kuiper Belt can be further subdivided according to the shape and inclination of the orbits of the objects (see the overview below).

Protoplanetary disc
*The Sun and the rest of the Solar System formed from a huge cloud of gas and dust, the **presolar nebula**, which at some point collapsed (possibly because of a nearby supernova or a 'passing' star). As this presolar nebula shrank, it got hotter (like in a bicycle pump the air gets hotter when you inflate your tire).*
*The cloud rotated and as it shrank, the rotation accelerated. Just think of a figure skater doing a pirouette and making herself smaller by bringing her arms close to her body: she will spin faster! We call this the **Law of conservation of angular momentum**.*
*As a result, the nebula flattened out, due to the accelerating rotation, and formed a disc: the protoplanetary disc (or 'proplyd'). For this reason, the eight planets move approximately in the same plane around the sun: the **plane of the ecliptic** (see page 10).*

Formation of planets
The solar nebula (see above) consisted of 0.6% metals and silicates and 2.5% ices (see main text). The rest, nearly 97%, was hydrogen and helium. So it makes sense that the rocky planets remained small (they formed from only 0.6% of all the available material). The giants had five times as much material available (they also have silicates and metals in their cores), while the fastest-growing planets, Jupiter and Saturn, could grow almost indefinitely, after obtaining a mass of about ten Earths, by absorbing hydrogen and helium.

Astronomical Units
Distances in kilometers lead to very large numbers: the distance to Eris, for example, is on average 10 152 336 385 km. For this reason, we use the Astronomical Unit (AU) in the Solar System and its immediate surroundings: 1 AU is equal to the distance from the Earth to the Sun, or about 149.6 million km. Eris is then on average at 67.86 AU.

***Bottom left**: the young star Vega also has an asteroid belt, with warm regions on the inside and cold regions outside. Illustration NASA.*
***Bottom, right**: car tires used to have rubber inner tubes. Maybe some still do.*

Overview of the Solar System

Lagrange points
There are two points around which (much smaller) objects can move stably in the same orbit as a more massive object, like a planet: the Lagrange points L4 and L5. This was determined in 1772 by the French mathematician Lagrange.
There are three other points, L1, L2 and L3. These are unstable points in which the trajectory of an object changes rapidly. L1 is on the side of the planet that faces the Sun, L2 is on the other side of the planet and L3 is on the other side of the Sun. The Lagrange points L4 and L5 lie approximately 60° in front of (L4) and behind (L5) the planet. That means that Neptune Trojans move at some 2.3 billion km from Neptune, leading or trailing the planet.
Jupiter has over 2,000 Trojans (asteroids, largely made up of rocks and metals).
*See the illustration **below right**.*

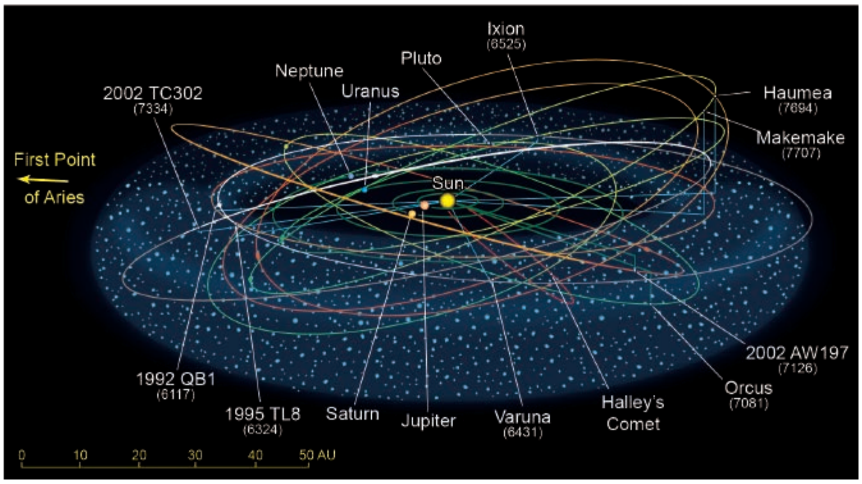
***Bottom left**: a drawing of the Kuiper Belt, from my book 'Genieten van het zonnestelsel'. Note: an ellipse in the (two-dimensional) drawing can be a circle that you see from the side! Haumea has the orange orbit.*
***Bottom right**: the 5 Lagrange points in planetary orbits. The L1 and L2 points of Earth are 1.5 million km away. Many space telescopes are placed in that L2 point, like the European Gaia and the new James Webb Space Telescope (the successor to the Hubble). Launched in December 2013, Gaia is a space telescope designed to map a billion stars and other objects.*

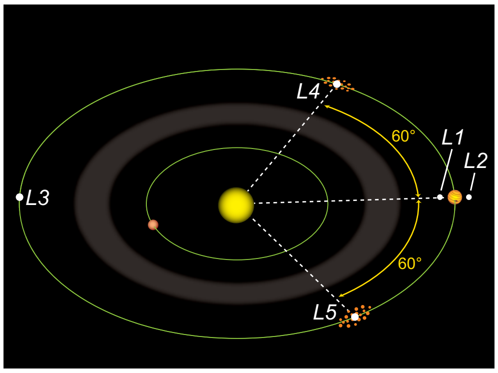
The Oort Cloud
Even further away we find the *Oort Cloud*, which consists of two parts. The **Inner Oort Cloud** is actually a donut-shaped ring (so a belt!) stretching from the Kuiper Belt (about 55 *AU*) to about 20,000 *AU* from the Sun (see page 5). Farthest away we find a globular cloud, the **Outer Oort Cloud**, from 20,000 to at least 50,000 AU (and possibly even 125,000 AU) from the Sun. See the cards for the distances to scale. It could well be that nearby stars also have Oort Clouds and those Oort Clouds may even overlap. The resulting disturbances could send *long-period comets* toward the Sun, or to another star!

TNO's and CNO's
Objects with orbits beyond Neptune's are called **Trans-Neptunian Objects**, or **TNOs** (*trans* means *over*, in this case *beyond)*. The Kuiper Belt is also located in that area.
The objects in the Kuiper Belt, the **Kuiper Belt Objects** (**KBOs**), can be thrown out of orbit by the gravitational influence of Neptune and may also be sent towards the Sun: **Cis-Neptunian Objects** (**CNOs**); *cis* means *on our side*.
We know of two types of CNOs: Centaurs and Neptune Trojans. **Centaurs** are ice dwarfs in the region of the giant planets, with elongated orbits. Their orbits are not stable because they are influenced by the largest planets. Eventually they will end up in the inner Solar System and if they don't collide with the planets or the Moon they end up in the Sun. There aren't that many, as far as we know. Luckily. Chariklo (card 20) is such a Centaur.
The Neptune **Trojans** are ice dwarfs that have been associated with Neptune for a long time. As of 2020 we know 29 Neptune Trojans. What's special is that they have the same orbit as Neptune! Is that possible? Yes, there are two points where light objects can have stable orbits around a massive object (see *Lagrange Points*, right column).

Beyond Neptune
The TNOs are further subdivided according to their orbits (although that is not always easy). This all leads to the following overview:

1. Kuiper Belt
- The **classic KBOs** (between approximately 6.2 and 7.2 billion km – on our scale 62-72 m). These move in neat, almost circular orbits (most slightly tilted), indicating that they are barely affected by Neptune's gravity. Examples are Makemake, Quaoar and Salacia.
- The **resonant KBOs** are KBOs that are trapped by Neptune's gravity, giving them elongated (i.e. eccentric) and tilted orbits. Various resonances are possible:
  - 2:3 resonance, the plutinos, such as Pluto, Orcus, and Ixion; they have orbital periods ('years') of about 250 years. Dwarf planets beyond Neptune's orbit are also called **plutoids**.
  - 2:1 resonance, unofficially named the **twotinos** (for the '2:1' resonance and with a wink to the plutinos); there are no known KBOs among them. Their orbits are less stable than those of the plutino's, so more have disappeared. They have orbital periods of about 330 years. The area of the twotinos is seen as the outer limit of the Kuiper Belt, at 47.8 AU, beyond which few objects are known; we call this the **Kuiper Cliff**.
  - 2:5 resonance, the largest known object of this group being 2002 TC302 (see *Scattered Disc*, below); they have orbital periods of about 410 years.
  - 4:7 resonance, the largest known object there is 1999 CD198; they have orbital periods of about 290 years.
  - 3:10 resonance, the largest known of which is 2007 OR10, since 2019 called Gonggong; they have orbital periods of about 550 years.
  - Many more resonances are possible.





2. Scattered Disc
The Scattered Disc is another belt around the Sun, but this one is called a disc, a huge disc around the Sun that is billions of kilometers thick. It extends from the middle of the Kuiper Belt well into the Oort Cloud (roughly from 5 to 15 billion km - on a scale of 50 to 150 m, and more than 100 m thick!).
Objects in that disc are called **Scattered Disc Objects**: **SDOs**. These have been chased away from the Kuiper Belt, as it were. How did that happen?
Beyond the edge of the Kuiper belt, where the twotinos move, TNOs are disturbed by orbital resonances with Neptune to such an extent that their orbits become very unstable. Those orbits are very eccentric and strongly tilted, sending them out of the Kuiper Belt, in all directions: they are thus *scattered*.
Centaurs are now believed to be actually SDOs chased by Neptune into the realm of the giant planets. Well-known SDOs are the dwarf planet Eris, the large TNO Gongong (2007 OR10) and the smaller 2002 TC302 (all three are also in resonance with Neptune).

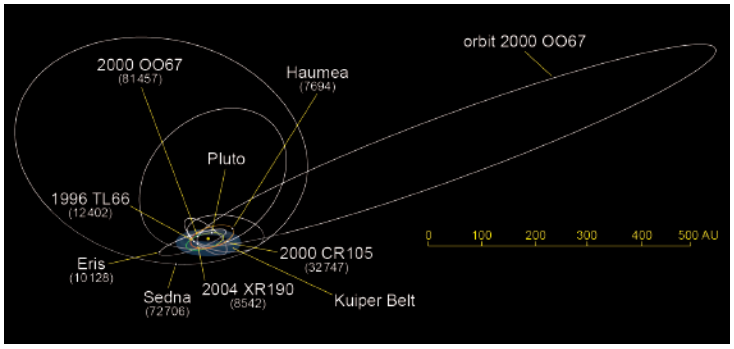
3. Detached objects
Detached objects are objects that are so far from the Sun that they are no longer affected by Neptune's gravity. In publications you may find other names for these types of objects, such as **Extended Scattered Disc Objects**: **E-SDO**.
Their orbits are very elongated, with *perihelia* between 40 and 52 AU, and *aphelia* from 64 to well over 260 AU. Some nine Detached Objects are securely identified (2021) and some 60 more are likely *DOs*. The large ones are on the order of 300 to 800 km in diameter, but those dimensions are very uncertain. Sedna's case is uncertain: is it a Detached Object or an *OCO*? Or an object of its own class, a *Sednoid* (see below)? This shows once again how difficult it is to classify those distant objects. What is certain is that an object that has been chased away from the Kuiper Belt can also return to it, or even come nearer to the Sun.

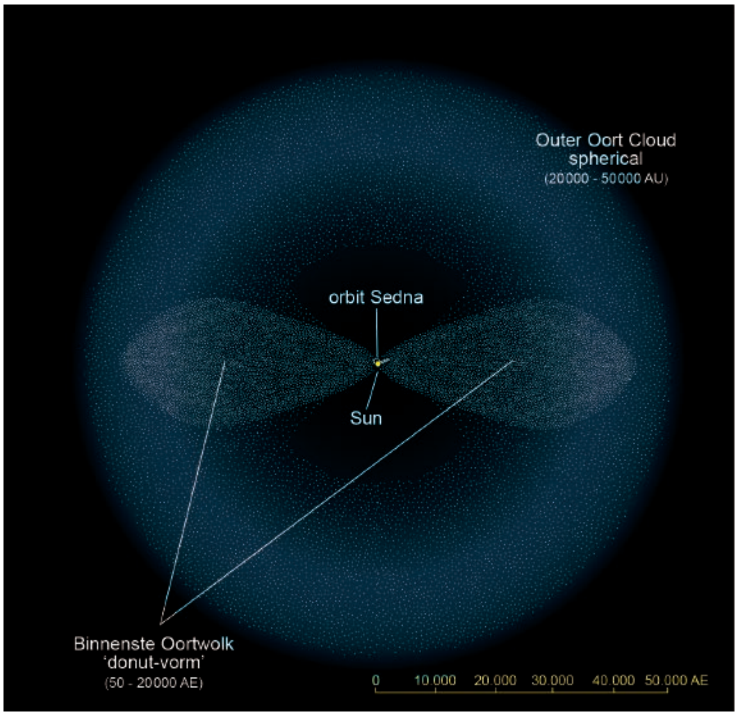
Sednoids
What is certain is that the Sednoids are special, either as part of the Detached Objects or as a separate group. I will list them here as a separate group. There are three official sednoids, Sedna, 2012 VP113 and Leleākūhonua. They have their perihelia at about 80 AU (on scale 120 m) and an inclined orbit that takes them mainly below the plane of the ecliptic, and in the same direction. Their perihelia are therefore also on the same side of the Sun (see below under *Planet Nine*).

Oort Cloud Objects
Objects in the Inner Oort Cloud are called Oort Cloud Objects, or **OCOs**. They also have a very eccentric and strongly inclined orbit, but the planets are not to blame for that. It is not known how many large objects there are in the Oort cloud, but there may be large ones, as large as a planet. The next paragraph shows that we are far from done with the exploration of the Solar System.
Sedna was initially seen as OCO but it has now also been placed in the separate class of *Sednoids*. Another OCO is 2000 CR105 (265 km in diameter), but it is also regarded as a Detached Object. There are a few more known objects in this area.

Dutch astronomers
*Dutch astronomers have always played an important part in astronomy, which is shown by the fact that the **Kuiper Belt** and the **Oort Cloud** were named after Dutch astronomers!*
In the 20th century, scientists started thinking about comets. It was believed at the time that comets had existed since the formation of the Solar System, 4.5 billion years ago. When a comet comes close to the Sun, it loses a lot of gas and dust, forming its tail. If a comet has done visited the inner Solar System a number of times, it has no material left to form a tail and has become a 'dead' comet. Comets should have run out long ago! Still, new and active comets were regularly seen.
(continued on page 9)

***Bottom left**: a drawing of the orbits of some objects in the Inner Oort Cloud, from the **Solar System Overview** series in my book 'Genieten van het zonnestelsel'. The orbit of Pluto is indicated to compare this image with that of the Kuiper Belt on the previous page.*
***Bottom right**: a drawing of the Outer Oort Cloud, the fifth in the Overview series. This is a cross section. The Oort cloud is a spherical cloud of icy objects, at least 50,000 AU in diameter, but it may even be as large as 125,000 AU.*





Planet Nine

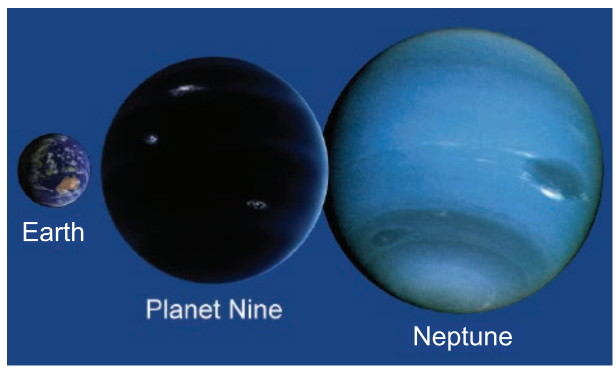
(continued from page 7)
In 1950 the Dutch astronomer Jan Hendrik Oort theorised that there should be billions of comet nuclei at an enormous distance from the Sun, so far away that the heat from the Sun has hardly any influence on them. Comets can come from all directions, not just the ***plane of the ecliptic****, in which the planets orbit. That could only be explained if there is a large, spherical cloud around and centered on the Sun. It would also neatly explain the fact that there is apparently an almost infinite supply of comet nuclei: an estimated 1000 billion!*
Honesty commands to say that another astronomer came to the same conclusion in 1932, the Estonian astronomer Ernst Öpik. Therefor the cloud is often called the Oort-Öpik Cloud We now call that cloud of comets the Oort Cloud. It was not until 2000 that the first object that probably comes from the
(continued on page 9)

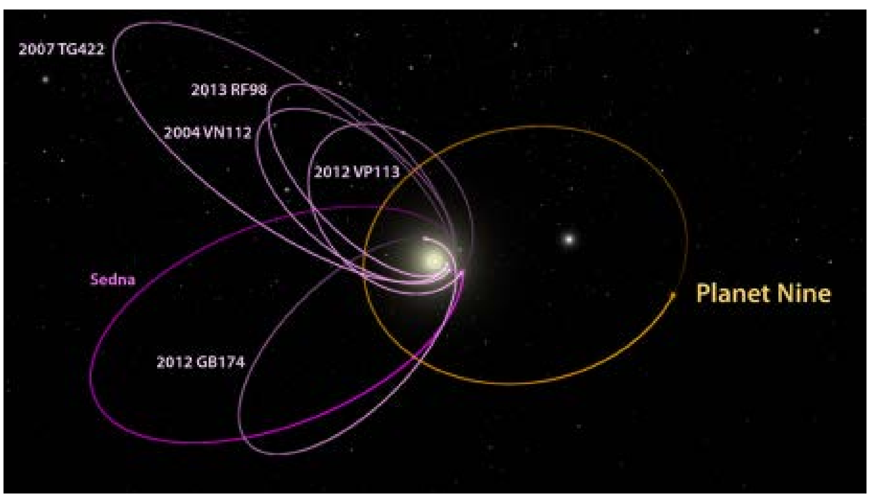
Bottom left*: the orbits of the six TNOs and the possible orbit of the as yet hypothetical ninth planet. You can see that the orbits of the six obects point in the same direction.*
Top right*: an artist impression of Planet Nine.*
Second from top*: Mike Brown (left) and Konstantin Batygin.*
Third from top*: comparison of Planet Nine's possible diameter with that of Earth and Neptune.*
Bottom right*: the Solar System is a misfit compared to the planetary systems we now know around other stars. You see that most exoplanets that we know now have a mass between that of the Earth and Neptune, while the Solar System has no planets in that class. Or does it?*

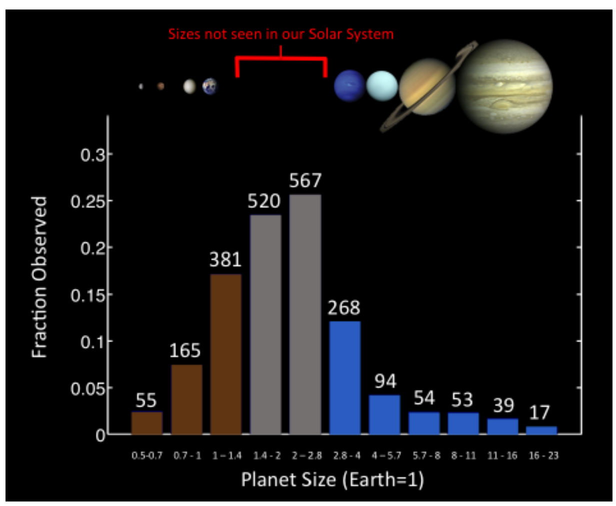
Planet Nine

A ninth planet?
Three more *Sednoids* have been found, all orbiting in the same direction as Sedna and VP113, but pointing to a point above the ecliptic plane (they mainly move above that plane). So all six have their *perihelion* on the same side of the Sun. I call them Sednoids here but I'm not sure if we should call them that.
If this configuration had happened by chance (1:15,000 chance), it could never have lasted very long. There must be something else going on. These could be, for example, *orbital resonances* caused by a distant, large planet!

With the help of the computer
After the discovery of 2012 VP113 and other similar objects, in 2014 Mike Brown and his colleague Konstantin Batygin started thinking about a hypothetical planet that would keep the six TNOs in their orbits so neatly. Even though they thought such a planet itself unlikely. They had the computer calculate many possibilities, always with a slightly different orbit, distance and mass of the imaginary planet. The computer models that corresponded to what we see suggest a kind of mini-Neptune orbiting at a huge distance: in the scale model between 300 and 1800 m! Dubbed 'Planet Nine', this planet would have an orbit inclined by 30° to the ecliptic plane, opposite to the Sednoids' inclination. Thus, its perihelion would be on a side of the Sun opposite the perihelia of the TNOs. Besides, the planet must be around aphelion when the small objects are around their perihelion. The latter is now the case (the small ones are around perihelion) so if there is a Planet Nine, it would be very far away, and therefore difficult to detect (especially if it happens to be in the direction of the Milky Way). There is a card for the hypothetical planet in the set MDL-SS2.







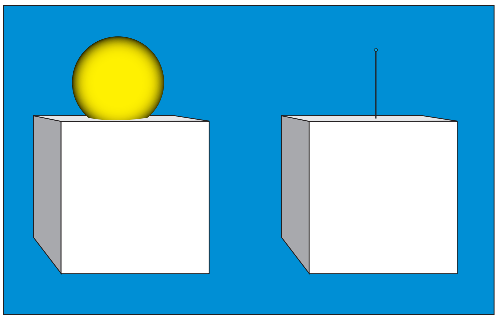
Making a 3D model

Crafting yourself

Marble, pins and...
Even more fun and prettier than a scale model in cards is of course a scale model that consists of real models, of **balls**. Based on the information on the cards, this is easy to do.
It may seem easier said than done with this scale, but it's not that bad. However, a caliper is useful. And you'll find that you can develop an obsession with getting balls and balls of all sizes... like I did.
On this scale (1:100 billion), the Sun is 1.4 cm: the size of an ordinary marble! The giants Jupiter and Saturn are much smaller: 1.4 and 1.2 mm. That's about the size of the head of a small pin, the kind you find in newly purchased shirts. They are not all the same size, so it shouldn't be a problem to find two that are quite different in size.

Bases
Of course you have to place the models on something. In my first model on this scale I used styrofoam cubes (see drawing). You can glue the marble on it, and insert the pins and steel wires (see below) in no time. You can also think of something else as a basis for the models. You can stick or glue labels on the sides of the bases with the names and other information (size and distance).

Smaller objects
How do you make the smaller objects? I used very thin steel wire for this, thew kind you can buy on a roll. It is available from 0.1 mm and that kind of wire is used for beaded necklaces, among other things.
You also need hobby paint in various colours: black, white, blue, yellow, dark red, rust red, gray brown. You can use turpentine-based paint (Humbrol, Revell) or water-based (acrylic), as long as you can use it in droplets.
Of course you want the little balls to come about as high as the two pins, so cut pieces of steel wire that are long enough to stick into the cube, and still stick out high enough.
Straighten the threads with a knife or something similar.
Now paint or spray all steel wires matte black (there is matte black primer!). When they are dry you can stick them in the cubes.

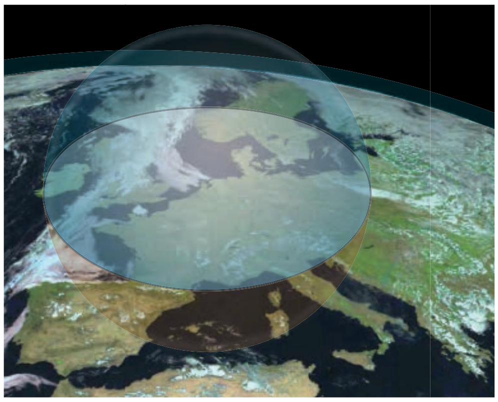


Dipping in paint
Then you can make the planet models by very carefully dipping the ends of the wires in the paint. (Remember to stir the paint well.) You really just need a small dot and for this it is best to drip a thin layer of paint on a saucer.
Of course you will use paint in the right color: red for Mars, blue for Earth, Uranus and Neptune, white for Venus, dark gray for the Moon and Mercury. For the smaller celestial bodies it is best to consult a book about the Solar System or the internet.
Uranus and Neptune are bigger than the Earth, and the Earth is bigger than the Moon. How do you make a ball bigger than the other balls? That is not so difficult: by dipping the tip in the same color of paint more than once you can create the larger worlds. Make sure that the first coat of paint is completely dry, otherwise the ball will deform.

Perfect size?
It doesn't really matter if the ball is perfectly the right size, because what matters is the effect of a very small ball at the right distance. No one can tell whether a sphere is 0.05 mm, or 0.1 mm...

Other stars
You can also include nearby stars in your scale model. That will be a matter of two large marbles, some normal marbles, and a whole bunch of pins.
Sirius and Procyon are marbles about 2.8 cm in size (as big as large marbles). The stars of Alpha Centauri are about the size of the Sun (Alfa Cen A is 17 mm, Alfa Cen B is 11 mm). However, most stars are small red dwarfs (see *Red dwarfs*, in the right column).

3D printer
When you have a 3D printer, you can of course print balls in exactly the right size. And you should contact me... because I would be very interested!



(continued from page 7)
Oort cloud was found (OCOs, see page 7).
In 1951 the Dutch/American astronomer Gerard Kuiper suggested in a scientific journal that there must have been some kind of disc in the early Solar System, which consisted of very many small objects. They were probably planetesimals that could not have formed planets there because the gas and dust had been too thin there. He suggested that many periodic comets, which we see in an flattened region around the Sun, must have originated from this disc. However, he assumed that disc no longer existed. From 1988 the hypothetical disc was called the Kuiper Belt. The first Kuiper Belt object (after Pluto!) was found in 1992 (1992 KB1).
In this case there were also others that had the same idea; Kenneth Edgeworth wrote an article in 1943 to that effect. It wasn't a matter of plagiarism, all came to the conclusion bij themselves and for varying reasons.

Red dwarfs
Most stars are small, dark and cool, and therefore red in color: red dwarfs. In fact, in our region 80 to 85% of all stars are red dwarfs. Most are about 1.5 times larger than Jupiter (in diameter), although they have much more mass, and are therefore more compact). Jupiter was 80 times too light to become a star. That means that for red dwarfs in the scale model we can use big head pins, with plastic heads (there are those with a red head!).

***Bottom left**: you can cut small blocks of polystyrene foam and use these to put the models on.*
***Bottom right**: the card **16 - And further...** about nearby stars, tells, among other things, that only 23 stars can be found in a radius of 1000 km around the card of the Sun in this scale model. This picture shows the size of that sphere, centered on my home town, Amersfoort: 1000 km into space (blue here; the ISS moves at an altitude of about 410 km), 1000 km into the earth (colored brown), from the west coast of Ireland to the Baltic States, and from central Sweden to northern Spain and Italy! It shows us how empty it is in the Milky Way galaxy. It's even emptier beyond!*

Background information

***Bottom left**: An ellipse has no center but two foci (F1 and F2). All orbits in the solar system are elliptical (with the sun in one of those foci), but some are nearly round and others very elongated. There are two extremes in an elliptical orbit: the perihelion (the point closest to the sun) and the aphelion (the farthest point). See also the main text.*

Bottom right: the orbital slopes of the planets and some other objects. You see that especially distant, small objects can have large orbital slopes (note Eris: more than 44°!).

***Helemaal onderaan**: als je de planeetbanen van opzij bekijkt zien zij er zo uit. Je ziet duidelijk een vlak waarin ze allemaal (ongeveer) bewegen. Je kijkt hier van een beetje bóven dat vlak dat we het **vlak van de ecliptica** noemen. Dat vlak is voor ons een soort referentie, waarmee we kunnen aangeven hoe scheef een baan is. Het denkbeeldige vlak wordt omsloten door een even denkbeeldige **ecliptica**. Dat is de 'weg' die de zon tegen de achtergrond van de verre sterren aflegt als gevolg van de beweging van de aarde op de zon. Denk je eens in dat je op een plein (tegen de wijzers van de klok) rond een lantaarnpaal loopt: je ziet dan de paal tegen een steeds weer andere achtergrond. Meer hierover lees je in het boek Genieten van de sterrenhemel en de planisferen.*

Explanation of terms

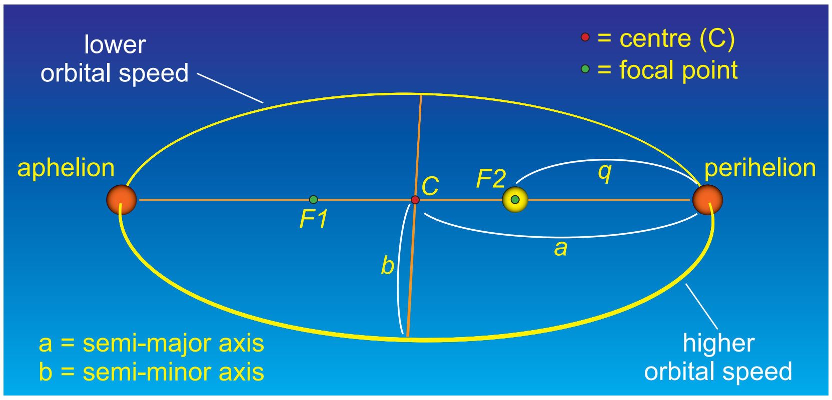
Periods
Every planet, dwarf planet, satellite or other object has two movements: one around its axis and one around the Sun or a planet (or other object because there are ice dwarfs, asteroids and even comets with a moon).
The movement about the axis is called **rotation**, and the period required for one rotation is the **rotation period**. The movement of an object around the Sun or planet is called its **orbiting**, the **orbit**, and the time required for one round is called the **orbital period**.

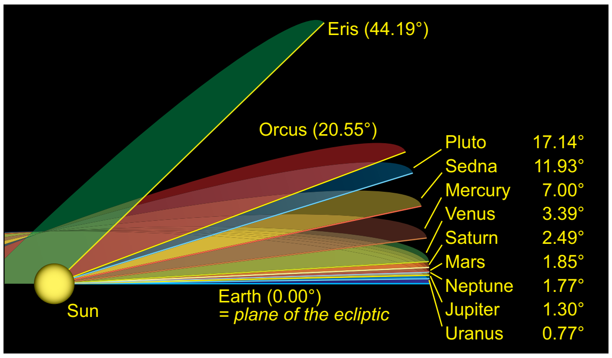
Inner planets and inner planets
We speak of *inferior planets* when their orbit lies within that of the Earth. That's just Mercury and Venus. The *superior planets* have their orbits beyond Earth's orbit: Mars, Jupiter, Saturn, Uranus, and Neptune.
When we talk about the **inner planets**, we mean the four rocky planets.

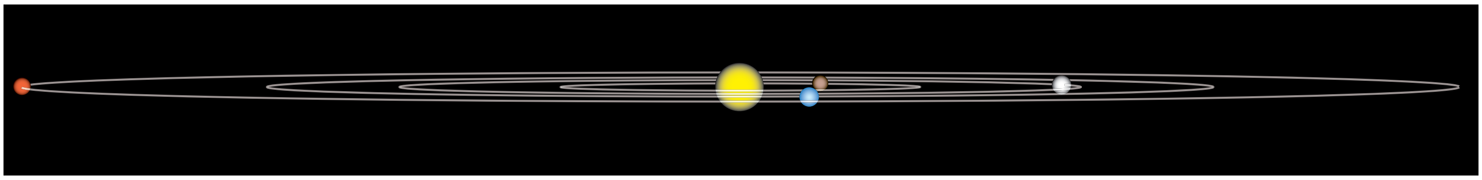
A plane
The eight planets lie nicely in one plane: the plane in which the Earth orbits the Sun. The plane of the Earth's orbit is also called the **plane of the ecliptic**. It is used as a reference plane for all other objects. It is an imaginary plane, not something you can touch. You can imagine such a plane by taking the floor as an example. Imagine that the Sun is in the center of the floor, and that large and small balls move in orbits around that Sun, rolling across the floor. This gives a good representation of planets that move in the same plane around the Sun (see text blocks in the left column).
Only... Mercury moves in a quite tilted orbit, one that is inclined 7 degrees from the plane of the ecliptic (see illustration bottom right). So Mercury is usually a bit below or above 'the floor', in the scale model up to 7 cm below or above it.
All planets have a greater or lesser tilted orbit, or **orbital inclination**, as the illustration shows. Smaller objects can have greater orbital inclinations than planets: Pluto's orbit is inclined about 17°, Eris' almost 45°.

Ellipses
Besides, the orbits of the celestial bodies are not neatly circular, but less or more elliptical. Pluto, for example, has a very elliptical orbit that allows it to come closer to the Sun than Neptune, which it was from 1979 to 1999 (44.4 m in the model, in 1989). However, it is at its furthest 73.8 m from the Sun in the scale model. See also the left column and the illustration about ellipses.
An ellipse has no center but two **focal points**. The classic way to draw ellipses is with two nails or thumbtacks and a piece of string with the points tied together. The further apart the nails are, the longer and narrower the ellipse becomes. If you put the nails right next to each other, the result will be something that is almost a circle. Solar System objects have an elliptical orbit with the Sun at one of their focal points.
An ellipse has a major and a minor *axis*. The **major axis** is a line that runs through the focal points and connects the two opposite points on the ellipse. The **minor axis** is perpendicular to this and runs through the center of the major axis (see the illustration).
The **semi-major axis** is also often used (also by me) as the **average distance**, although that is not quite correct. By the way, the cards give the average distances unless otherwise stated.

Eccentricity
Eccentricity is the measure of the deviation from a pure circle. The eccentricity (e) is defined as $e = 1 - q/a$, where q is the *perihelion* distance, and a is the semi-major axis (the mean







distance). The greater the resulting value, the more elongated the orbit. A circle has the value 0. Sedna has a very large eccentricity, with 0.85491: its *aphelion* is at about 936 AU and its perihelion at 76 AU (on scale 1400 m and 114 m).

Perihelion and aphelion

Whether a planet's orbit is slightly or extremely elliptical, the distance from the planet to the Sun changes during an orbit. The point of a planet's orbit closest to the Sun is called the **perihelion** (*peri* means *close*). If an object passes through the perihelion, we speak of a **perihelion passage**.
The **aphelion** is the point of orbit at which the planet is furthest from the Sun (*apo* means *far*). A planet moves faster around the Sun when it is closer to our star, so at its perihelion it has the highest orbital speed; the orbital speed is lowest in aphelion. We have similar points in orbits around the Earth (**perigee** and **apogee**) and other planets (**periapsis** and **apoapsis**).

Orbital resonance

If the orbital periods of two celestial bodies are are related by a ratio of small integers, they will exert a regular, periodic gravitational influence on each other. So, this happens when the orbital periods have a ratio that you can write as a whole fraction: 1:2 ('one in two'), 2:3, 3:5 etc. In the latter case, one object orbits the Sun three times in the same time the other object does that five times.
We call this *orbital resonance* and it enhances the mutual attraction. This usually leads to a situation that is not stable. Both objects will change their orbit in such a way that the resonance no longer exists. However, sometimes a resonant system can be self-correcting and thus stable. For example, three moons of Jupiter, Ganymede, Europa and Io, are in a 1:2:4 resonance: when Ganymede has completed one orbit around the planet, Europa has done two and Io four. These also is a stable 2:3 resonance between Pluto and Neptune.
Resonances from Saturn's moons cause gaps and divisions in Saturn's rings, and zones in the Asteroid Belt have been 'cleaned up' by Jupiter's unstable resonance: the Kirkwood Gaps. Neptune rules the Kuiper Belt in the same way.
A special case is 1:1 resonance, so when two celestial bodies have the same distance to the Sun, are actually in the same orbit. This is a very unstable situation that once helped the *protoplanets* to 'clean' their zone, a prerequisite for being called a planet (see page 4). Ceres and the asteroid Pallas are in about 1:1 resonance but they are too small to influence each other.

Distances

Distances in the Solar System are indicated in km, or in **Astronomical Units** – **AU**. An AU is the average distance from Earth to the Sun: about 150 million km. That way you can indicate distances within the Solar System with smaller numbers. For example, the distance to Neptune is about 4.5 billion km, or 30 AU. Pluto is on average 6 billion km: 40 AU. The Oort Cloud may extend to 125,000 AU!

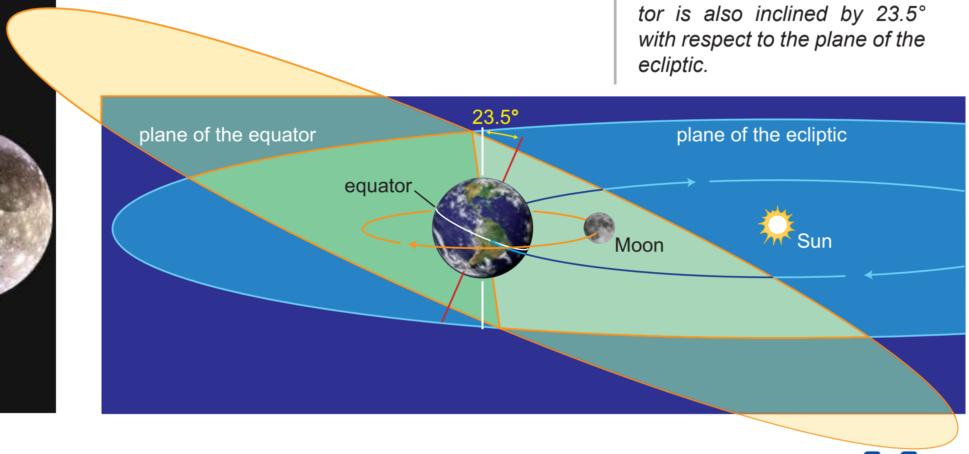
Satellites (moons)

The earth has a **natural satellite**: the Moon. In 1609, Galileo Galilei, who became the first man to use a telescope to study the night sky and celestial objects, discovered the four major satellites of Jupiter: the Galilean satellites. Later they were also discovered at Saturn and the other planets, and they came to be called **moons**. There are now about 220 known in the Solar System.

***Bottom left**: the four Galilean moons are Jupiter's largest satellites. Here you see them in a collage of photos taken by Voyagers 1 and 2 (in 1979). From top to bottom, they are Io, Europa, Ganymede, and Callisto. That is also the order in distance from the planet (Io is the closest of the major moons). The three moons are in a 1:2:4 resonance (see main text).*
Ganymede is the largest moon in the Solar System. It is bigger than the planet Mercury! The same is true for Saturn's moon Titan (in size the number 2 moon in the Solar System. However, the small planet Mercury has more than twice as much mass, consisting mainly of rock and metal, as opposed to the icy Ganymede.
The nice thing about a picture like this, with the four moons to the same scale, is that you can use it for an ad-hoc scale model! Based on the sizes they are here, Jupiter is over 62 cm in size, and the distances from the moons to the planet are:

Io	*184 cm*
Europa	*293 cm*
Ganymedes	*467 cm*
Callisto	*822 cm*

***Bottom right**: in addition to the plane of the ecliptic, we also have the **plane of the equator**. This is the extension of the equator on Earth. Because the Earth is tilted by 23.5° (that is why an Earth globe is also tilted), the plane of the equator is also inclined by 23.5° with respect to the plane of the ecliptic.*



Using the Planet Path

Tape Measures

You can't set up the planet path without a tape measure for a reasonable distance. Or rather a few tape measures. These tape measures come in different lengths (just google 'tape measure'). They are on a reel so you can roll them up quickly. I have used measuring tapes with a length of 30 m for years, but now I have two of 50 m with which I can quickly, easily and properly measure the scale model up to and including Eris. It is hndy if you are able to leave the tape of one reel on the floor and start the next one at that point.

***Below**: in my oldest Planet Path I glued the card holders (see **Card holders** on the next page) to blocks of wood. A hole was drilled in those blocks (not all the way through the block) into which a piece of threaded rod of 1 m length was inserted. The other side of the threaded rod sits in a larger block of wood standing on the ground. That too is not drilled through and through. An extra hole in the largest block of wood, which had been drilled through and through, offers the option of securing the block with a peg to prevent it from being blown over.*
***Bottom right**: this is what that setup looked like.*
***Top right**: for the presentation of the new scale model, in 2015, and for the picture for the cover of the set and this brochure, I came up with a simpler, cheaper solution, with sticks and pegs (see the picture on page 2). You can push those sticks into the ground (better make a hole first with something sturdy, a large tent peg or something like that) and quickly set up a planet path.*

The Planet Path in Practise

Introduction
There are two questions when you start with a Planet Path: where and how do I set it up, and what do I do with it?
The first question makes sense: the cards must be presented in some way so that the target audience can see them. The second question depends on what your intention is, what you want to achieve with the target group. So it's about:

1. Setup
   - Selection of cards
   - Physical setup (poles, etc.)
   - Location
2. Presentation

Selection of cards
It is of course important to first make a choice from the cards. That choice depends on the length of the planned path (the length of the street or corridor (at school), the space in a park, etc. But the choice is also determined by what you want to portray, the target group (with smaller children you may want to reduce the number of objects to the Sun, the planets and for example Pluto). You should always have a goal in mind: do you just want to give a good overview of the Solar System, or a complete one; or do you have a specific goal, such as presenting the outer regions of the Solar System? Or even a much narrower goal, such as a closer acquaintance with the inner Solar System and the Asteroid Belt.

Location
The location must offer the opportunity to have a good overview of the entire Planet Path, in a straight or at worst a slightly curved line. This can be in the schoolyard, in a long corridor at school or in a park. The scale model depends on the available space. Or better 'length', because we have just decided to set up the scale model in one line.
That **length** must be at least 45 m if you want it set up to and including Neptune. However, if there is space, I would definitely place Pluto and some other ice dwarfs because they give a good view of outer regions of our Solar System. Pluto is also still very popular, especially among the youth, and represents a whole new class of celestial bodies: the *dwarf planets*.
Incidentally, you can also reduce the distances, for example to hang the scale model in a small space, but remember that the sizes are then no longer correct!

A Unique Planet Path

It is ideal to be able to use a path of 101 m in length, so that the other large dwarf planet, Eris, is also present.
Some cards are impossible to place in their correct position (such as those of the Oort Cloud and 'And further…', about nearby stars). You can place it at the end of the path and treat it there. If you're giving a presentation or lesson, it's helpful to have examples to hand for the distances: 'Voyager 1 is near that church tower', 'The nearest next star (Proxima Centauri) is in Paris', etc.

Setting up your Planet Path
But how should you place or hang the cards? That also depends on the situation. In a corridor of the school, the stands can be used, so that the cards can be placed on tables or chairs, which are placed at the right distances. But the cards also have a hole with which they can be hung on the walls.
You can also pin them to slats or sticks. This has great advantages because you can stick those sticks in the ground in a lawn. Then you are not dependent on the availability of walls in the places you need them. Furthermore, it is a cheap solution because you only need a number of sticks on which you have glued cloth pegs with wood glue. Then you can put the cards in it. See also the back cover of the sets.
Handy teachers will be able to devise their own set-up.
If you are going to set up the Planet Path for children, it is great to let them do the measuring, determining where the cards should be placed. That is very educational in it own right!

Presentation or lesson
Okay, you've got it set up now, what are you going to do with it? There are two options: you let the students or your audience walk past the cards and read the texts; or you give a lesson or presentation yourself: 'A Journey through the Solar System'.
I don't need to pay any attention to the first option, i.e. letting people explore the Solar System themselves, except that it is great fun to give (school) children assignments in groups and have them answer questions.
What is especially interesting is what you can do with the Planet Path in a lesson, or just a fun presentation for family, friends and neighbourhood kids.

Cardholders
To keep the cards clean and dry, you can order our special PVC cardholders, or displays. They have a flat bottom that allows them to be better absorbed in a suitable structure for your Planet Path. Below you see an image of these cardholders.
See also: ***https://www.walrecht.nl/en/ordering/books-posters-and-other-products/build-it-your-self-products***.

Left: *in my 12-part astronomy course, originally set up for teachers of primary and secondary schools, I put the students to work, setting up the Planet Path themselves! And they are happy to do so. Here students of the first pilot are busy placing the posts as accurately as possible.*
Bottom left: *another picture taken during my teacher training course. You can clearly see here how far the posts reach. The path is a bit kinked (that's okay) and is about 80 m long. For that we had to place it diagonally because that allows longer path! On a small square behind the hedges in the distance, the standards (cards) have been collected that do not fit within those 80 m.*
Bottom right: *when presenting the new Dutch scale model in 2015, the cards were simply pinned to a fence with thumbtacks (photo Frank Kosterman).*

Using the Planet Parth

***Top left and bottom right**: two more pictures of my new own standards. These are perfect for my use but of course a bit too complicated and expensive for most users.*
They consist of axle stands (which are intended to be placed under a car) of which the T has been ground off the central part. In the remaining hole of the pipe I clamped PVC pipe (it just fits). On top is a loose 'head' with the card holder, a sort of cup for the 3D models and information about the scale model.

***Bottom left**: part of my 3D scale model at scale 1:100 billion. These can be combined with the new setup, placed in the 'cup' mentioned above, so that I can show the cards and the 3D models at the same time.*

Purpose and knowledge

When you give a presentation, you have to ask yourself what you want to say, what you want to teach your audience. For example, you can give a lot of information about the Sun, the planets and the other members of the Solar System. That's good and will be appreciated. However, anyone can, disrespectfully said, look it up on the internet or in a book. (The perfect combination would be to give a PowerPoint presentation with all information and wonderful pictures first, and then go set up the Planet Path.)
You can also tell about the differences and similarities between the worlds at different distances from the Sun, about groups of objects (Earth-like planets, gas giants, ice giants, asteroids, Kuiper Belt objects, etc.) and other things for which the Planetary Path is naturally well suited. What will put off many potential tour guides is the knowledge you need to tell a good story. But that's not much of a problem at all. If you read the cards themselves carefully, you already have enough material for a great presentation! Later you can go further and further, by looking up information on the Internet or in book, and of course following the scientific developments. Remember it's all new to your audience and anything you can teach them is welcome!

Encore

When you have finished the 'journey', it is especially fun and educational with children to let them pick up the cards (so possibly pull the stick out of the ground) and then give them one last assignment. Each child takes a planet or other object, only the Sun remains. Now have them walk in a large 'circle' around the Sun (card), counterclockwise. Be careful of any road or cycle path in the area, because it will become big circles! It's a lot of fun, but it also teaches them something, for example why planets that are further from the Sun take longer for one orbit. That's not entirely scientifically correct, because an object's orbital speed is slower the farther it is from the Sun, but it still gives a good idea.

Comparison with the dimensions

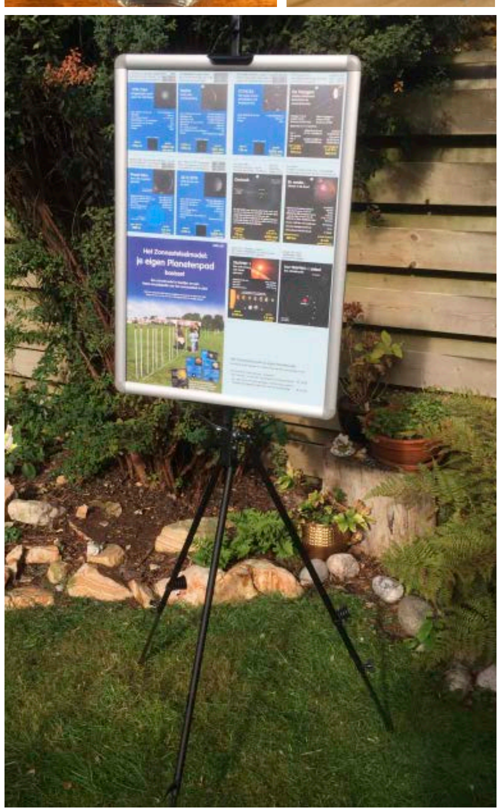
On the cards I have indicated what the diameter of each object is to scale, with below something to compare that size with. I have used comparative material as clearly as possible for this. Here's an overview. Except for the thickness of spider web thread, it is always one **particle**, so one grain of sand or one cigarette smoke particle.

	approx.:	**examples:**
head pin	1.5 mm	Jupiter, Saturn
coarse sand	0.5 mm	Uranus, Neptune
normal sand	0.25-0.5 mm	Planet Nine?
fine sand	0.1 mm	Earth, Venus
very fine sand	0.05 mm	Mars, Mercury
talcum powder	0.02 mm	Pluto, Eris, Moon
fog droplet	0.01 mm	Salacia, Quaoar, Sedna
red blood cell	0.007	Vesta, 2002 AW197
thickness of silk	0.002	Hermione, Chariklo
cigarette smoke	0.00002	Halley's Comet
oxygen atom	0.0000005	object of approx. 50 m

Errata

Nothing known, yet.

Index



***Left, top**: I'm giving the Tour through the Solar System during the 2020 edition of my astronomy course. I use the older standards here.*
***Left, bottom**: I have almost twice the number of new standards than the 32 'heavies' (with axle stands). Therefore I can show more of the cards, but I had to make extra 'heads' that contain the cards (see below).*
***Top, centre**: this eloborate structure, which I call 'a head' (I somehow always have to invent a new jargon with muy inventions...), contains the cardholder and card; a connection pipe for the above mentioned cup, which can hold a 3D model; information about what it is ('This is a scale model, please don't go moving these standards!').*
***Top, right**: the new standards are music stands, of which I only use the 'foot' part. They perform wonderfully, stand very firm and are much lighter than the old standards.*
***Right, bottom**: a fine solution to show all cards that cannot be placed at their correct distances, as they may be too far away (Proxima Centauri would be at 400 km), is this display, on an easel. I also have one for the start of the model (i.e. near the Sun), to have a clear starting point when I do more than one tour.*