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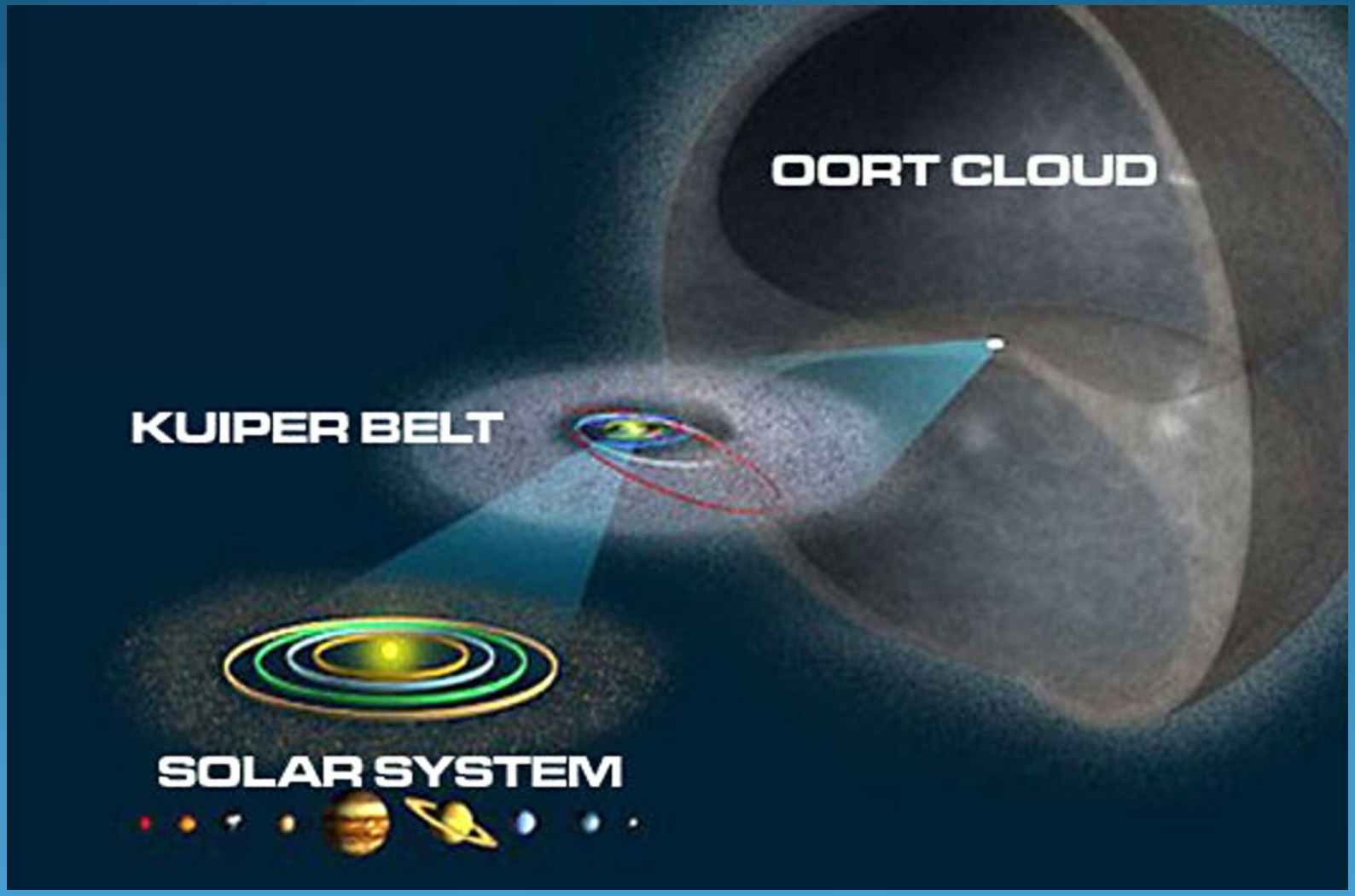
The Oort Cloud



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The Oort Cloud

Structure of the solar system

The sun

The planets

Kuiper belt

Oort cloud

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The Oort Cloud

Structure of the solar system

The sun

The planets

Kuiper belt

Oort cloud

Comets – long period and short period
Formation of the Oort Cloud
Sun's gravitational limit
Next star
Tracks of the stars over time
Disruption of the Oort cloud

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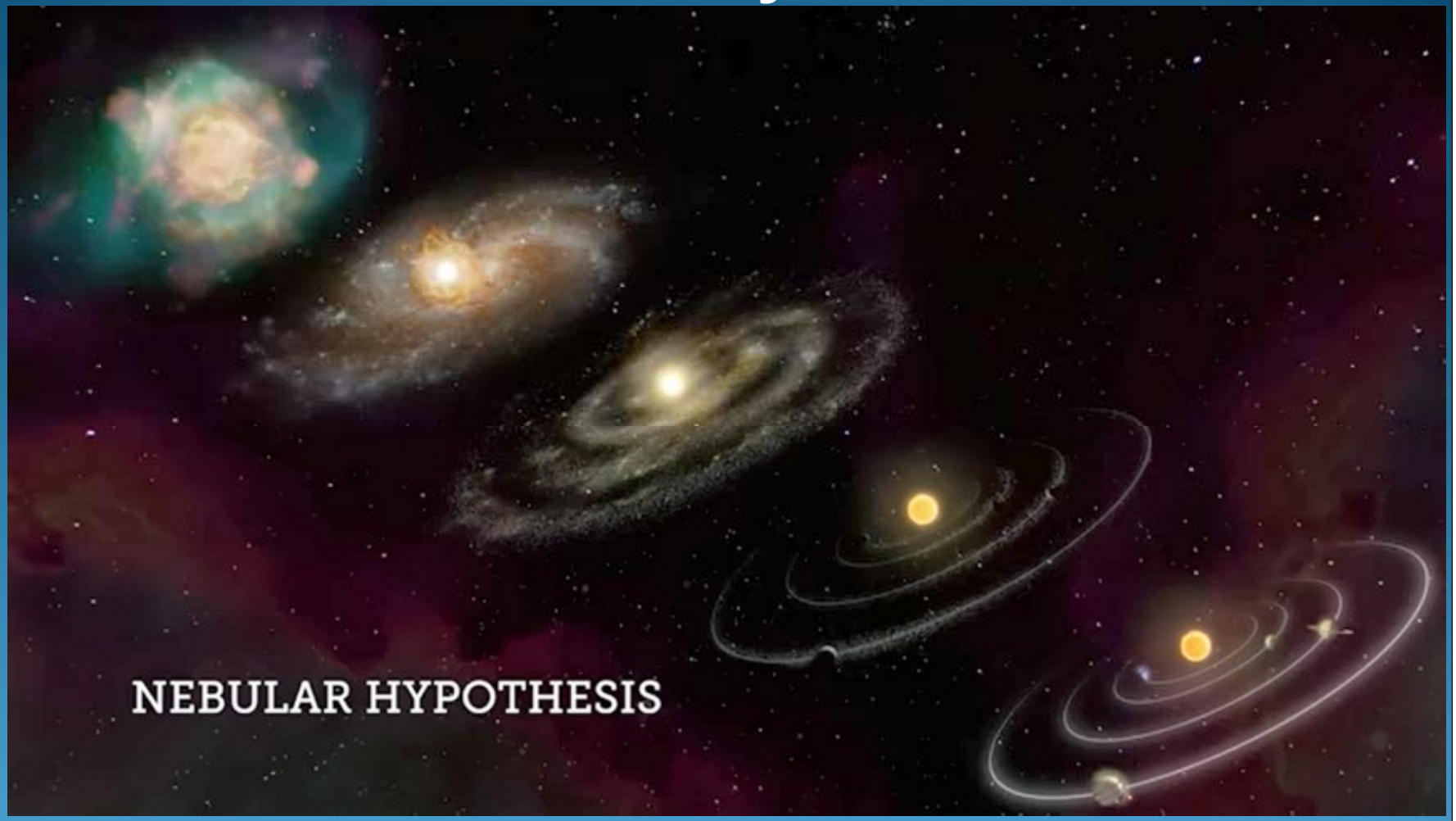
The Solar System



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The Solar System

Extract of video from Lincoln Learning Solutions

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The Solar System

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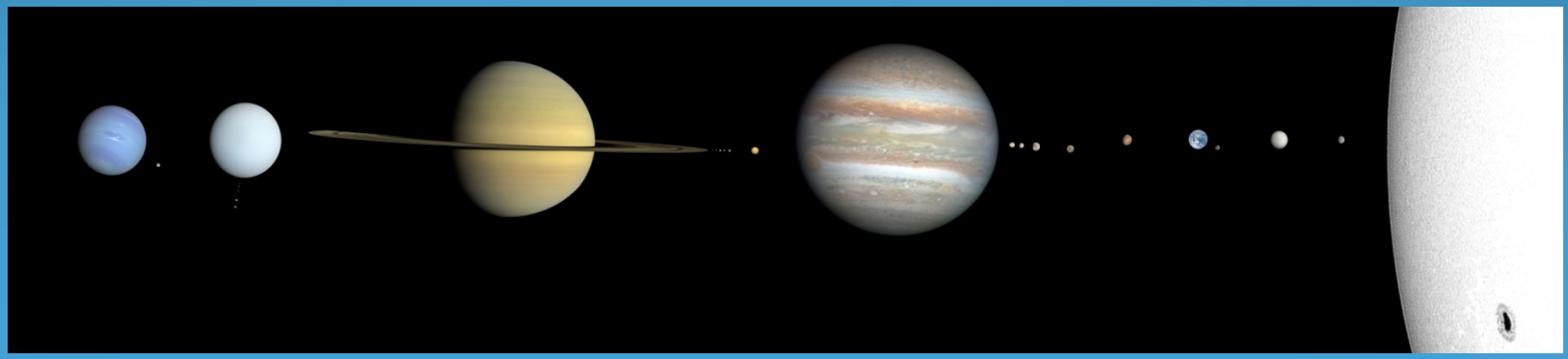

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The Solar System

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	Dia	Mass	Moons	Dist	Gravity	Weight (kg) cf Earth
SUN	109	333,000	-	-		-
Mercury	0.4	0.1	0	0.4 AU	0.4 g	27
Venus	0.8	0.9	0	0.7 AU	0.9g	64
Earth	1	1	1	1 AU	1 g (9.8 m/s2) [Moon 0.17g]	70 (11st) [13]
Mars	0.5	0.1	2	1.5 AU	0.4 g	26
Jupiter	11	318	95	5 AU	2.5 g	177
Saturn	9	95	146+	10 AU	1.1 g	75
Uranus	4	15	27	19 AU	0.9 g	62
Neptune	3.9	17	14	30 AU	1.1 g	79

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The Solar System

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Looking further out

Beyond Neptune

We find

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The Solar System

The Kuiper Belt

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The Kuiper Belt

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First hypothesised in 1930

Suggested that Pluto may have been an “ultra Neptune body”

Also proposed as a reservoir of comets

Kuiper presented a paper in 1951 which speculated on the existence of a disc of debris

In 1992 observations showed that such a zone existed.

By 2012 over 1,000 bodies had been discovered

Estimated to extend from 30 AU to 55 AU

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The Oort Cloud

And then the Oort Cloud

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The Oort Cloud

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By 1900 it was known that there are 2 types of comet.

Short period that seem to have aphelion of less than 50 AU

& long period whose orbits can extend out to thousands of AU.

Ernst Opik, in 1932, postulated the existence of a cloud at the edge of the solar system which was a reservoir for these long period comets.

In1950 Jan Oort was considering the issues around long period comets.

Questions that arose include:-

-The fact that these bodies appeared from all directions

-Some are travelling faster than short period comets

-As the orbits are highly elliptical and unstable they are unlikely to survive.

-They could be pulled away by a passing star, affected by the Galactic Tides, collide with the sun or be ejected by interactions with planets.

Oort's conclusion was that these bodies must be located in a general cloud of comets some 50,000 to 150,000 AU.

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The Oort Cloud

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1950BAN....11

BULLETIN OF THE ASTRONOMICAL INSTITUTES OF THE NETHERLANDS

1950 JANUARY 13 VOLUME XI NUMBER 408

COMMUNICATION FROM THE OBSERVATORY AT LEIDEN

LINK: https://articles.adsabs.harvard.edu/pdf/1950BAN....11...91O

THE STRUCTURE OF THE CLOUD OF COMETS SURROUNDING THE SOLAR SYSTEM, AND A HYPOTHESIS CONCERNING ITS ORIGIN,

BY J. H. OORT

The combined effects of the stars and of Jupiter appear to determine the main statistical features of the orbits of comets.

From a score of well-observed original orbits it is shown that the "new" long-period comets generally come from regions between about 50000 and 150000 A.U. distance. The sun must be surrounded by a general cloud of comets with a radius of this order, containing about 10^{11} comets of observable size; the total mass of the cloud is estimated to be of the order of 1/10 to 1/100 of that of the earth. Through the action of the stars fresh comets are continually being carried from this cloud into the vicinity of the sun.

The article indicates how three facts concerning the long-period comets, which hitherto were not well understood, namely the random distribution of orbital planes and of perihelia, and the preponderance of nearly-parabolic orbits, may be considered as necessary consequences of the perturbations acting on the comets.

The theoretical distribution curve of $1/a$ following from the conception of the large cloud of comets (Table 8) is shown to agree with the observed distribution (Table 6), except for an excess of observed "new" comets. The latter is taken to indicate that comets coming for the first time near the sun develop more extensive luminous envelopes than older comets. The average probability of disintegration during a perihelion passage must be about 0·014. The preponderance of direct over retrograde orbits in the range from a 25 to 250 A.U. can be well accounted for.

The existence of the huge cloud of comets finds a natural explanation if comets (and meteorites) are considered as minor planets escaped, at an early stage of the planetary system, from the ring of asteroids, and brought into large, stable orbits through the perturbing actions of Jupiter and the stars.

The investigation was instigated by a recent study by VAN WOERKOM on the statistical effect of Jupiter's perturbations on comet orbits. Action of stars on a cloud of meteors has been considered by ÖPIK in 1932.

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The Oort Cloud

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The Oort Cloud is currently thought to be made up of 2 distinct zones;

A disc or torus, cf. the Kuiper Belt, stretching from around 2,000 to 20,000 AU

Plus a spherical shell which could extend out as far as 100/200 thousand AU.

That would take it half way to the nearest star, Proxima Centauri at 4.2 L.yr

However, although the hypothesis addresses many questions it is still hypothetical.

We haven't imaged any bodies in the Cloud – It's a long way off, the bodies are small and we haven't got the technology (as yet) to resolve anything .

The best resolution we can currently get with optical interferometry is 10^{-3} arcsec. A large object of 100 km in the Oort Cloud would be less than 10^{-5} arcsec.

The best estimates of it's composition are that most objects are made of ice of water, methane, ethane, carbon monoxide and hydrogen sulphide.

However, object 1996PW, possibly an Oort cloud object, is an rocky asteroid.

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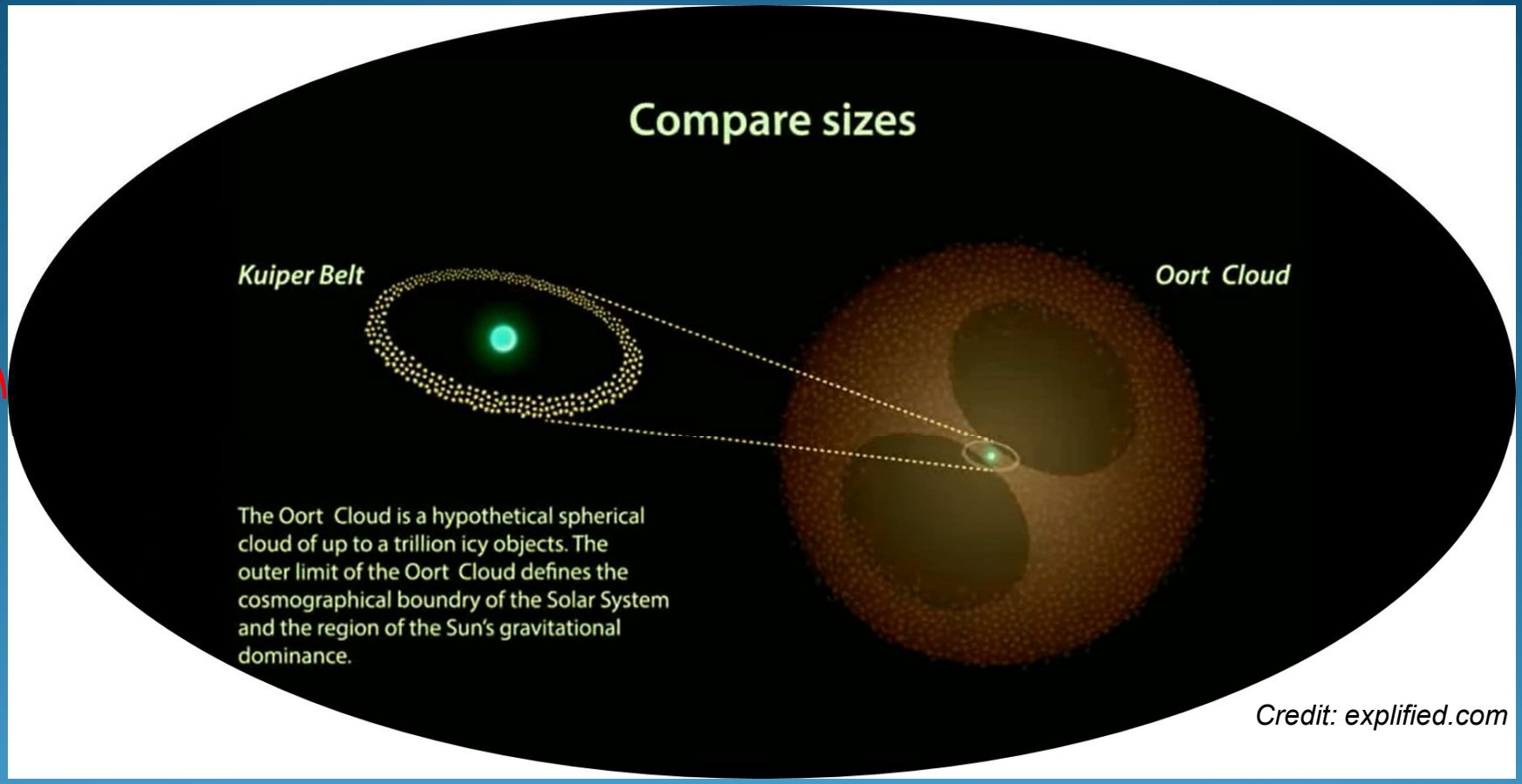
The Oort Cloud



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Voyager 1 was launched in 1977 – been travelling for 46 years
It is now 162 AU (15 billion miles) from Earth travelling at nearly 1 million miles per day
It will take 300 years to reach the inner edge of the Oort Cloud
And possibly another 28,000 to get through it.
Voy 1 will probably run out of power in another 2 years, long before reaching the Oort Cloud

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The Oort Cloud

So what do we think we know about the Oort Cloud?

It's a long way away
Its made up billions or even trillions of small bodies, dust etc
Mainly ices of various compounds and possible a couple of percent of rocky material.
It is the probable source of long period comets
It probably wasn't formed where it is now
The objects are only loosely held by the Sun's gravity
It will be disturbed by passing stars and galactic tides

What questions remain?

How and where did it form?
If not where it is now how did it get there?
Is it real or are there different theories that can explain the formation of the Solar System?
Have other stars also got the equivalent to our Oort Cloud?

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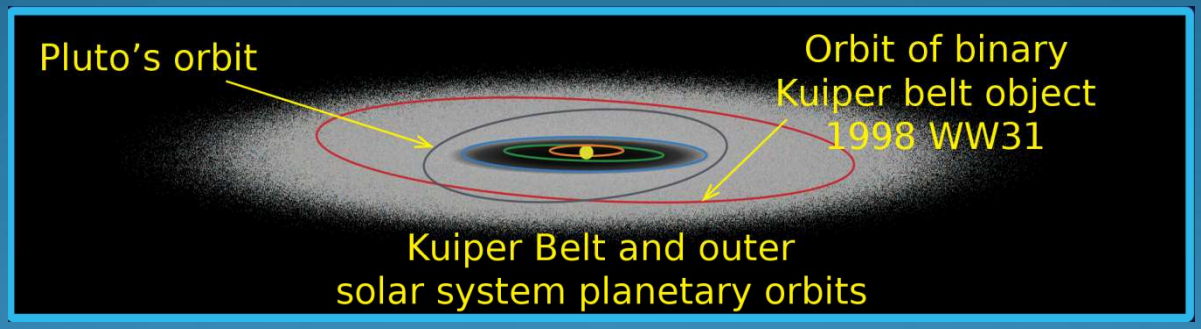
The Oort Cloud

How did it form when everything else is in a plane

As we know the planets, asteroid belt and the Kuiper belt are all in the same plane.



The reasons for this are understood – ie the nebula hypothesis for the formation of the Solar System.

If this is correct why is the Oort Cloud a sphere?

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The Oort Cloud

How did it form when everything else is in a plane

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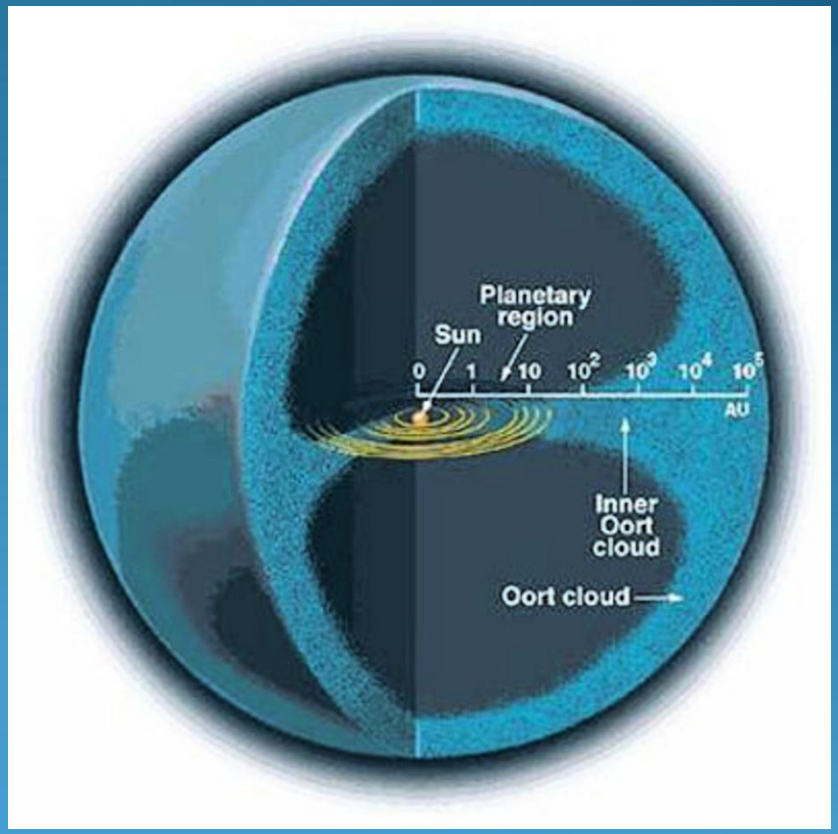
The current thinking, as mentioned on earlier, is that the Oort Cloud is composed of two differing geometric shapes.



First:-
the outer region - a sphere.
As described by Jan Oort in 1950

Second:-
the inner region - a torus/doughnut shape similar to the Kuiper, proposed in 1981

Although this structure looks very dense – almost a shell – the reality is completely different.

Paul Weismann in 1998, then studying the physics of comets in Pasadena, estimated the distance between these remnants as tens of millions of kms.

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The Oort Cloud

How did it form when everything else is in a plane

The further the initial building blocks of the Solar System are from the Sun the slower they will be moving.

In the planet forming regions they have sufficient energy to clump together when they collide.

Further out it is unlikely that they would be able to.

Therefore they must have formed closer to the sun.

Some 140 long period comets, assumed to be from the outer reaches of the SS, have been investigated.

These studies have revealed that their composition is similar to those of short period ones.

Another indication that all of these bodies were formed in the same regions and in the same plane of the Solar System

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The Oort Cloud

How did it form when everything else is in a plane

So the answer to the question is that:-

Oort Cloud bodies were either captured

OR

formed in the original flat(ish) plane of the solar system

In the planetary forming zone

Why is it now a sphere?

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The Oort Cloud

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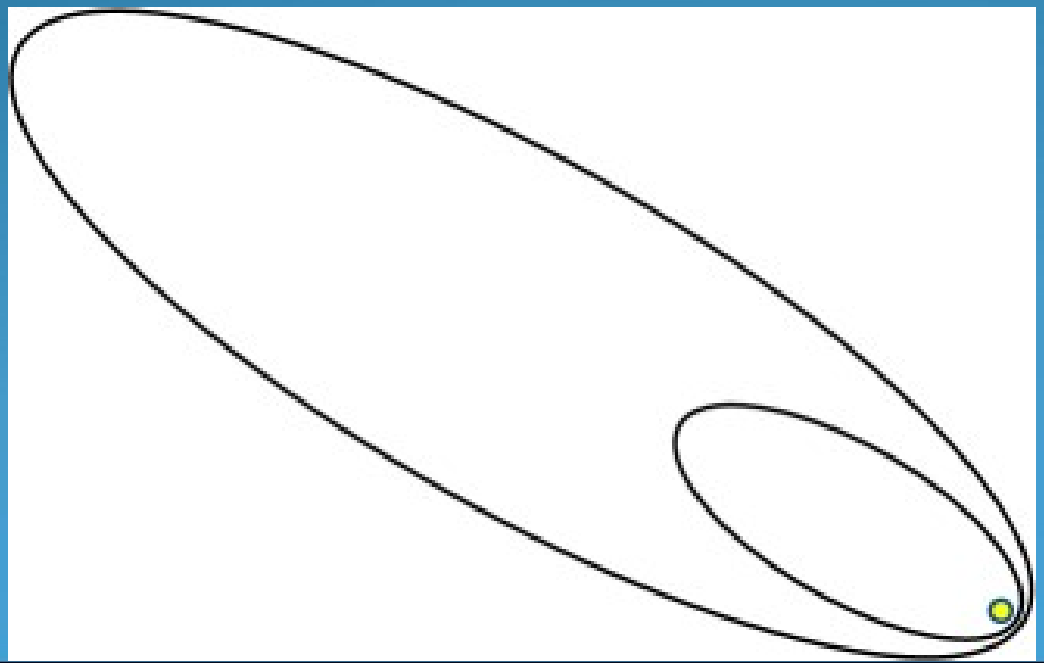
There are 3 properties that are used to describe orbits :-

Semi major Axis	size of the orbit
Eccentricity	shape of the ellipse, describing how much it is elongated. (Circle = 0)
Inclination	vertical tilt of the ellipse with respect to the plane



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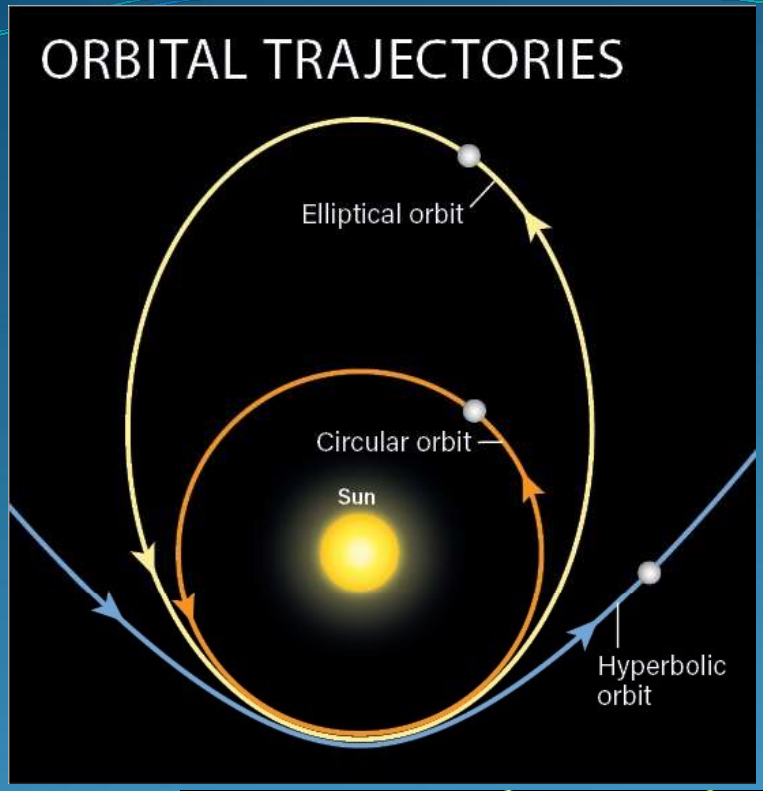

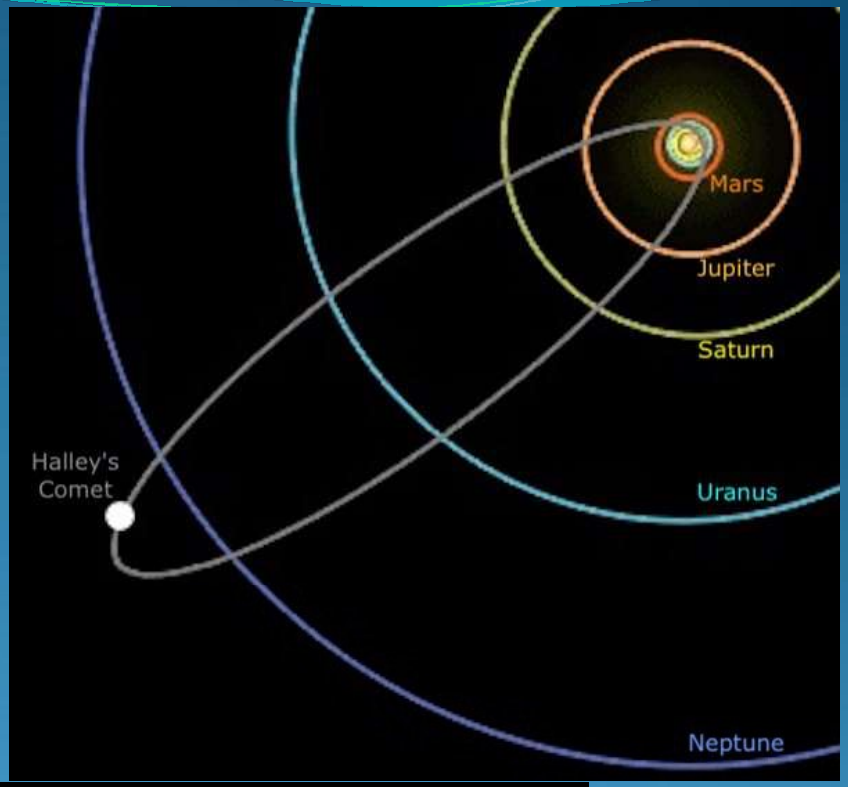

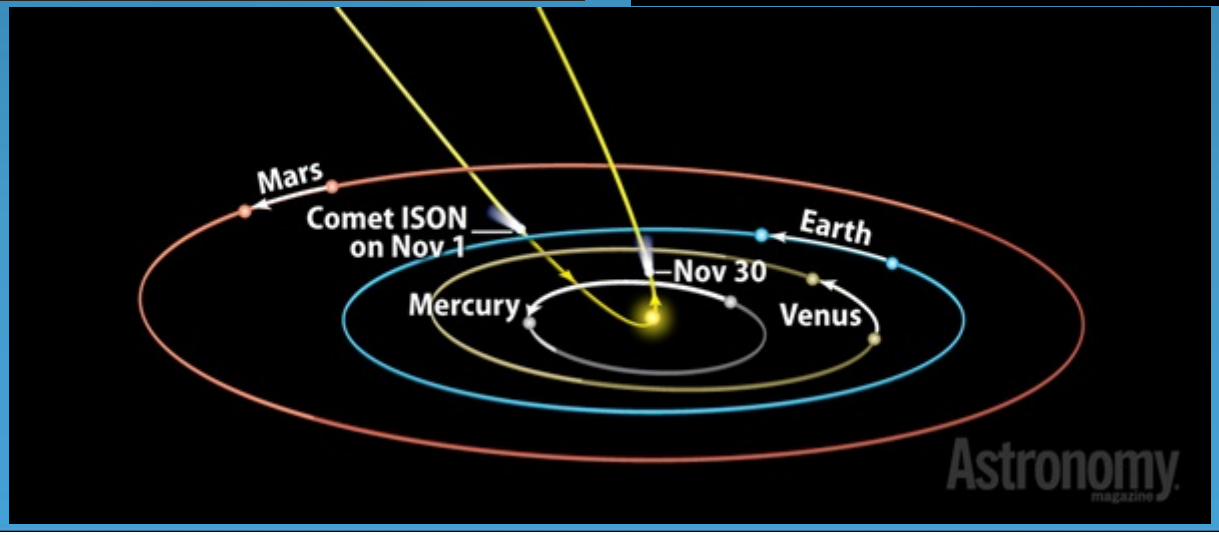

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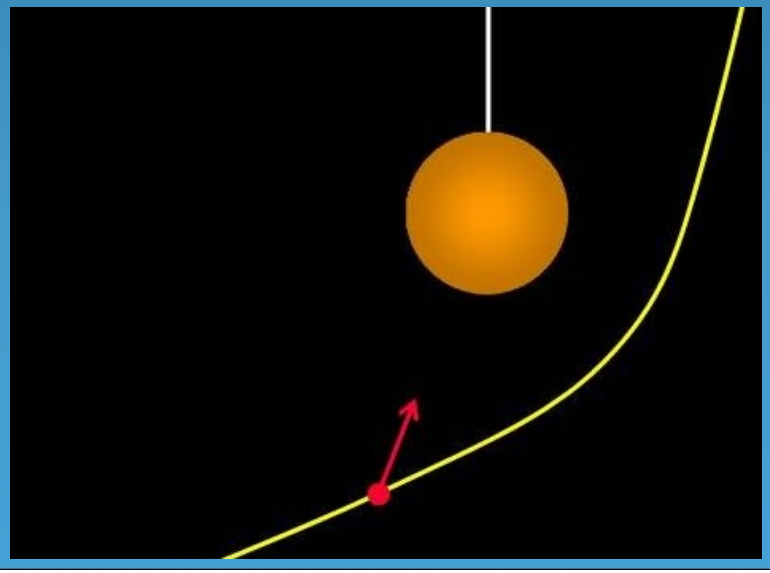
The Oort Cloud

How did it end up in a sphere then?

Having established that these cometery bodies formed in the disc of the Solar System the question remains how did they end up where they now are?

In the regions where these icy bodies formed there are the large gas giants; Jupiter, Saturn, Uranus & Neptune.

If the body gets close to one of these planets it will experience a gravitational kick which will cause scattering of the smaller body. This scattering will be random in nature.



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The Oort Cloud

How did it end up in a sphere then?

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There are 3 bodies involved in this interaction, the Sun, the planet and the comet.

As the comet has effectively no mass compared to the sun & planets a simplified 3 body interaction can be modelled.

In this type of interaction there is a quantity, called the Tisserand Relation , which is conserved.

There are 3 elements in this Relationship :- $1/2a + (a(1-e^2))^{0.5} \cos(i)$

The Axis (a) The eccentricity (e) and inclination (i)

As a consequence of this Relationship if the axis increases in size then so must the eccentricity and the inclination.

Thus, as the objects get scattered out the orbit becomes larger and more elliptical.

However, the perihelion (point nearest to the sun) will not vary as much as the aphelion (point furthest from the sun)

The Oort Cloud

How did it end up in a sphere then?

If this process, scattering by the large planets, were to continue at some point over the last 4.5 billion years the cumulative effect would increase the eccentricity to the point where the comet would fly out of the System.

Calculations suggest that by now the outer reaches of the Solar System would have been cleared out.

The fact that we still see long period comets was one of the observations that led Jan Oort to develop his theory.

The next influences that then appears on the scene are external to our Solar System.

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The Oort Cloud

How did it end up in a sphere then?

From time to time another star will wander close to our system.

These approaches with give another gravitational nudge to the outer parts where these comets are located.

This can then disrupt the orbital parameters of the comets reducing the eccentricity of the orbit pulling the comet out from the inner system.

The sun formed in a stellar nursery with many other stars.

There could may have been many interactions early in the life of the Solar System.

This doesn't happen very often now, the diagram shows what we expect over the next few thousand years.

But, as well as affecting our Oort cloud we may well be capturing bodies from these adjacent systems.

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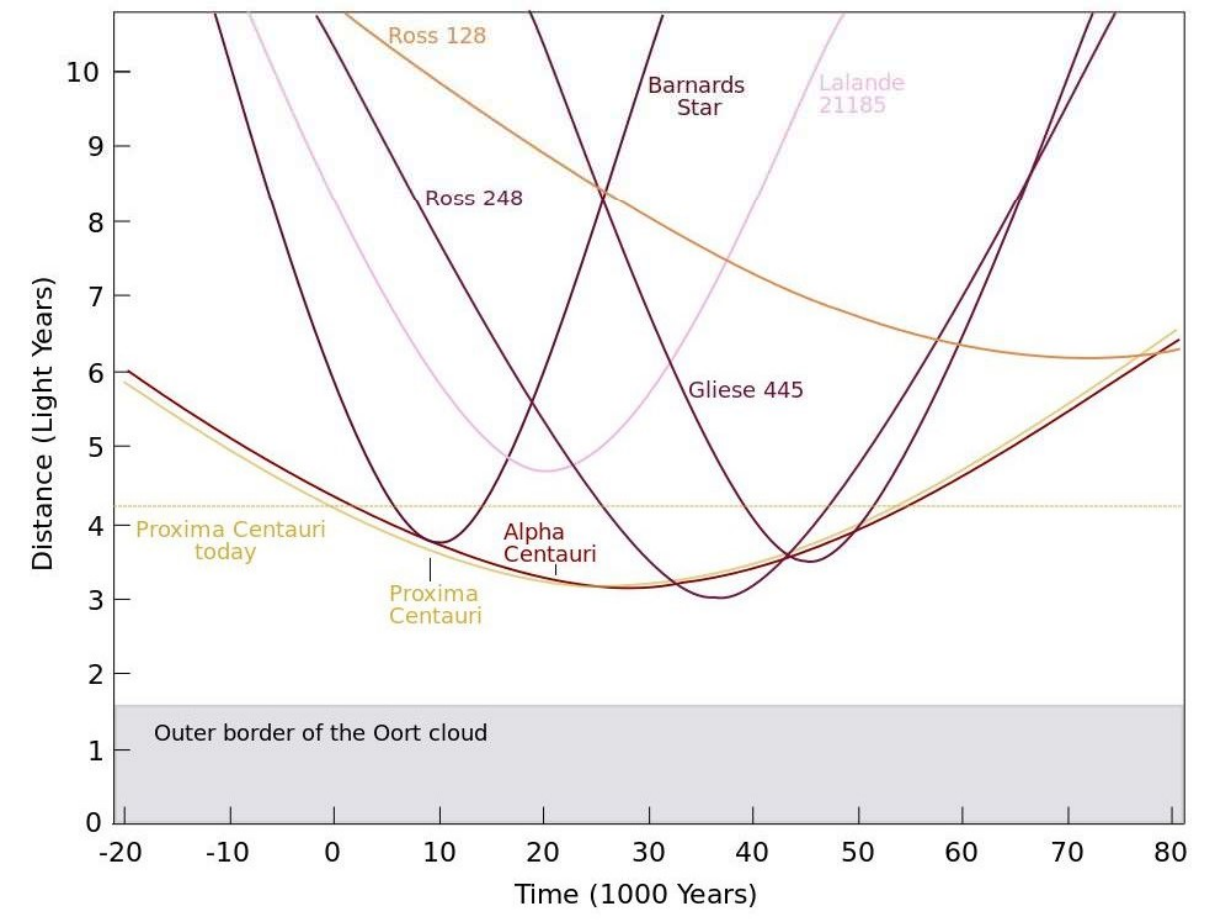
The Oort Cloud

This doesn't happen very often now, the diagram shows what we expect over the next few thousand years.

https://commons.wikimedia.org/wiki/File:Near-stars-past-future-en.svg



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The Oort Cloud

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But, as well as affecting our Oort cloud the Solar System will be capturing dust, comets, aesteroids etc from these adjacent systems.

The Oort Cloud

How did it end up in a sphere then?

In addition to this star interaction effect there is also the effects of the galactic tides.

This force probably has a greater effect on the Oort Cloud than star perturbations.

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The Oort Cloud

How did it end up in a sphere then?

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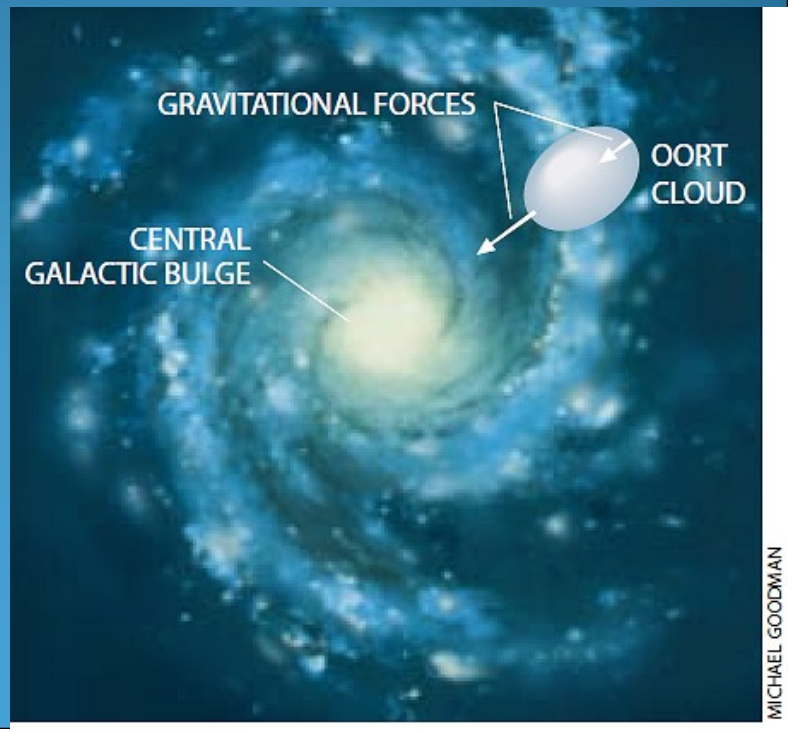
At the outer reaches of the Solar System the gravitational influence of the sun is minimal.

However, the centre of the galaxy has a huge concentration of mass which will pull on the Oort Cloud.

In addition the plane of the galaxy, will also have a gravitational effect on the Oort Cloud, but in a different direction.

These effects are analogous to the moon creating tides on the earth.

The combination has the effect of creating the shell of comets.



The Oort Cloud

To summarise then:-

-Comets form in the Solar System plane

-Many are scattered by the planets ending up in long period orbits with very high eccentricity

-They can then react with the external gravitational sources, ie passing stars and the galactic tide.

- Some may end up in long period, low eccentricity orbits.

The Oort Cloud

What effect does the Oort Cloud and these mechanisms have on Earth?

Disruption of the Oort Cloud by the external influences can result in comets showers heading into the inner system.

Some theories suggest that comet showers may be associated with epoch ending events.

The Oort Cloud

What effect does the Oort Cloud and these mechanisms have on Earth?

In fact, one study published this year, by Andrew MT Moore et al (Scienceopen.com), explores the hypothesis that a comet collision 12,800 years ago, caused a massive climate change.

This then led to the development of agriculture and the transition from a hunter gatherer lifestyle and the birth of permanent settlements.

The studies were carried out at the archaeological site at Abu Hureyra, Syria, the site of some of the world's first farming communities.

The comets believed to be involved are described as trans neptunium bodies.

The Oort Cloud

How about other star systems?

Are they expected to have Oort clouds?

Attempts to try and detect the presence of such structures around other stars have so far not been positive.

It is difficult trying to detect small exo-planets never mind small comet bodies or diffuse clouds of debris.

However, if the same laws of physics apply, which we assume is the case, there is no reason to not suppose that many systems also host their own equivalent to our Oort Cloud.

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The

End