# Kuiper belt

The Kuiper belt / ?ka?p?r / or Dutch pronunciation : [ ' køyp?r ] , sometimes called the Edgeworth ? Kuiper belt , is a circumstellar disc in the Solar System beyond the planets , extending from the orbit of Neptune ( at 30 AU ) to approximately 50 AU from the Sun . It is similar to the asteroid belt , but it is far larger ? 20 times as wide and 20 to 200 times as massive . Like the asteroid belt , it consists mainly of small bodies , or remnants from the Solar System 's formation . Although many asteroids are composed primarily of rock and metal , most Kuiper belt objects are composed largely of frozen volatiles ( termed " ices " ) , such as methane , ammonia and water . The Kuiper belt is home to three officially recognized dwarf planets : Pluto , Haumea , and Makemake . Some of the Solar System 's moons , such as Neptune 's Triton and Saturn 's Phoebe , are also thought to have originated in the region .

The Kuiper belt was named after Dutch @-@ American astronomer Gerard Kuiper , though he did not actually predict its existence . In 1992 , 1992 QB1 was discovered , the first Kuiper belt object ( KBO ) since Pluto . Since its discovery , the number of known KBOs has increased to over a thousand , and more than 100 @,@ 000 KBOs over 100 km ( 62 mi ) in diameter are thought to exist . The Kuiper belt was initially thought to be the main repository for periodic comets , those with orbits lasting less than 200 years . However , studies since the mid @-@ 1990s have shown that the belt is dynamically stable , and that comets ' true place of origin is the scattered disc , a dynamically active zone created by the outward motion of Neptune 4 @.@ 5 billion years ago ; scattered disc objects such as Eris have extremely eccentric orbits that take them as far as 100 AU from the Sun .

The Kuiper belt should not be confused with the theorized Oort cloud , which is a thousand times more distant and is mostly spherical . The objects within the Kuiper belt , together with the members of the scattered disc and any potential Hills cloud or Oort cloud objects , are collectively referred to as trans @-@ Neptunian objects ( TNOs ) .

Pluto is the largest and most @-@ massive member of the Kuiper belt and the largest and the second @-@ most @-@ massive known TNO , surpassed only by Eris in the scattered disc . Originally considered a planet , Pluto 's status as part of the Kuiper belt caused it to be reclassified as a dwarf planet in 2006 . It is compositionally similar to many other objects of the Kuiper belt , and its orbital period is characteristic of a class of KBOs , known as " plutinos " , that share the same 2 : 3 resonance with Neptune .

## History

After the discovery of Pluto in 1930 , many speculated that it might not be alone . The region now called the Kuiper belt was hypothesized in various forms for decades . It was only in 1992 that the first direct evidence for its existence was found . The number and variety of prior speculations on the nature of the Kuiper belt have led to continued uncertainty as to who deserves credit for first proposing it .

### Hypotheses

The first astronomer to suggest the existence of a trans @-@ Neptunian population was Frederick C. Leonard . Soon after Pluto 's discovery by Clyde Tombaugh in 1930 , Leonard pondered whether it was " not likely that in Pluto there has come to light the first of a series of ultra @-@ Neptunian bodies , the remaining members of which still await discovery but which are destined eventually to be detected " . That same year , astronomer Armin O. Leuschner suggested that Pluto " may be one of many long @-@ period planetary objects yet to be discovered . "

In 1943 , in the Journal of the British Astronomical Association , Kenneth Edgeworth hypothesized that , in the region beyond Neptune , the material within the primordial solar nebula was too widely spaced to condense into planets , and so rather condensed into a myriad of smaller bodies . From this he concluded that " the outer region of the solar system , beyond the orbits of the planets , is occupied by a very large number of comparatively small bodies " and that , from time to time , one of their number " wanders from its own sphere and appears as an occasional visitor to the inner solar system " , becoming a comet .

In 1951 , in an article for the journal Astrophysics , Gerard Kuiper speculated on a similar disc having formed early in the Solar System 's evolution ; however , he did not think that such a belt still existed today . Kuiper was operating on the assumption common in his time that Pluto was the size of Earth and had therefore scattered these bodies out toward the Oort cloud or out of the Solar System . Were Kuiper 's hypothesis correct , there would not be a Kuiper belt today .

The hypothesis took many other forms in the following decades . In 1962 , physicist Al G.W. Cameron postulated the existence of " a tremendous mass of small material on the outskirts of the solar system " . In 1964 , Fred Whipple , who popularised the famous " dirty snowball " hypothesis for cometary structure , thought that a " comet belt " might be massive enough to cause the purported discrepancies in the orbit of Uranus that had sparked the search for Planet X , or , at the very least , massive enough to affect the orbits of known comets . Observation , however , ruled out this hypothesis .

In 1977 , Charles Kowal discovered 2060 Chiron , an icy planetoid with an orbit between Saturn and Uranus . He used a blink comparator , the same device that had allowed Clyde Tombaugh to discover Pluto nearly 50 years before . In 1992 , another object , 5145 Pholus , was discovered in a similar orbit . Today , an entire population of comet @-@ like bodies , called the centaurs , is known to exist in the region between Jupiter and Neptune . The centaurs ' orbits are unstable and have dynamical lifetimes of a few million years . From the time of Chiron 's discovery in 1977 , astronomers have speculated that the centaurs therefore must be frequently replenished by some outer reservoir .

Further evidence for the existence of the Kuiper belt later emerged from the study of comets . That comets have finite lifespans has been known for some time . As they approach the Sun , its heat causes their volatile surfaces to sublimate into space , gradually dispersing them . In order for comets to continue to be visible over the age of the Solar System , they must be replenished frequently . One such area of replenishment is the Oort cloud , a spherical swarm of comets extending beyond 50 @,@ 000 AU from the Sun first hypothesised by Dutch astronomer Jan Oort in 1950 . The Oort cloud is thought to be the point of origin of long @-@ period comets , which are those , like Hale ? Bopp , with orbits lasting thousands of years .

There is , however , another comet population , known as short @-@ period or periodic comets , consisting of those comets that , like Halley 's Comet , have orbital periods of less than 200 years . By the 1970s , the rate at which short @-@ period comets were being discovered was becoming increasingly inconsistent with their having emerged solely from the Oort cloud . For an Oort cloud object to become a short @-@ period comet , it would first have to be captured by the giant planets . In 1980 , in the Monthly Notices of the Royal Astronomical Society , Uruguayan astronomer Julio Fernández stated that for every short @-@ period comet to be sent into the inner Solar System from the Oort cloud , 600 would have to be ejected into interstellar space . He speculated that a comet belt from between 35 and 50 AU would be required to account for the observed number of comets . Following up on Fernández 's work , in 1988 the Canadian team of Martin Duncan , Tom Quinn and Scott Tremaine ran a number of computer simulations to determine if all observed comets could have arrived from the Oort cloud . They found that the Oort cloud could not account for all short @-@ period comets , particularly as short @-@ period comets are clustered near the plane of the Solar System , whereas Oort @-@ cloud comets tend to arrive from any point in the sky . With a " belt " , as Fernández described it , added to the formulations , the simulations matched observations . Reportedly because the words " Kuiper " and " comet belt " appeared in the opening sentence of Fernández 's paper , Tremaine named this hypothetical region the " Kuiper belt " .

= = = Discovery = = =

In 1987 , astronomer David Jewitt , then at MIT , became increasingly puzzled by " the apparent emptiness of the outer Solar System " . He encouraged then @-@ graduate student Jane Luu to aid him in his endeavour to locate another object beyond Pluto 's orbit , because , as he told her , " If we don 't , nobody will . " Using telescopes at the Kitt Peak National Observatory in Arizona and the Cerro Tololo Inter @-@ American Observatory in Chile , Jewitt and Luu conducted their search in much the same way as Clyde Tombaugh and Charles Kowal had , with a blink comparator . Initially , examination of each pair of plates took about eight hours , but the process was sped up with the arrival of electronic charge @-@ coupled devices or CCDs , which , though their field of view was narrower , were not only more efficient at collecting light ( they retained 90 % of the light that hit them , rather than the 10 % achieved by photographs ) but allowed the blinking process to be done virtually , on a computer screen . Today , CCDs form the basis for most astronomical detectors . In 1988 , Jewitt moved to the Institute of Astronomy at the University of Hawaii . Luu later joined him to work at the University of Hawaii 's 2 @.@ 24 m telescope at Mauna Kea . Eventually , the field of view for CCDs had increased to 1024 by 1024 pixels , which allowed searches to be conducted far more rapidly . Finally , after five years of searching , on August 30 , 1992 , Jewitt and Luu announced the " Discovery of the candidate Kuiper belt object " ( 15760 ) 1992 QB1 . Six months later , they discovered a second object in the region , ( 181708 ) 1993 FW .

Studies conducted since the trans @-@ Neptunian region was first charted have shown that the region now called the Kuiper belt is not the point of origin of short @-@ period comets , but that they instead derive from a linked population called the scattered disc . The scattered disc was created when Neptune migrated outward into the proto @-@ Kuiper belt , which at the time was much closer to the Sun , and left in its wake a population of dynamically stable objects that could never be affected by its orbit ( the Kuiper belt proper ) , and a population whose perihelia are close enough that Neptune can still disturb them as it travels around the Sun ( the scattered disc ) . Because the scattered disc is dynamically active and the Kuiper belt relatively dynamically stable , the scattered disc is now seen as the most likely point of origin for periodic comets .

= = = Name = = =

Astronomers sometimes use the alternative name Edgeworth ? Kuiper belt to credit Edgeworth , and KBOs are occasionally referred to as EKOs . However , Brian G. Marsden claims that neither deserves true credit : " Neither Edgeworth nor Kuiper wrote about anything remotely like what we are now seeing , but Fred Whipple did " . David Jewitt comments : " If anything ... Fernández most nearly deserves the credit for predicting the Kuiper Belt . "

KBOs are sometimes called kuiperoids , a name suggested by Clyde Tombaugh . The term trans @-@ Neptunian object ( TNO ) is recommended for objects in the belt by several scientific groups because the term is less controversial than all others ? it is not an exact synonym though , as TNOs include all objects orbiting the Sun past the orbit of Neptune , not just those in the Kuiper belt .

= = Structure = =

At its fullest extent , including its outlying regions , the Kuiper belt stretches from roughly 30 to 55 AU . However , the main body of the belt is generally accepted to extend from the 2 : 3 mean @-@ motion resonance ( see below ) at 39 @.@ 5 AU to the 1 : 2 resonance at roughly 48 AU . The Kuiper belt is quite thick , with the main concentration extending as much as ten degrees outside the ecliptic plane and a more diffuse distribution of objects extending several times farther . Overall it more resembles a torus or doughnut than a belt . Its mean position is inclined to the ecliptic by 1 @.@ 86 degrees .

The presence of Neptune has a profound effect on the Kuiper belt 's structure due to orbital resonances . Over a timescale comparable to the age of the Solar System , Neptune 's gravity destabilises the orbits of any objects that happen to lie in certain regions , and either sends them into the inner Solar System or out into the scattered disc or interstellar space . This causes the Kuiper belt to have pronounced gaps in its current layout , similar to the Kirkwood gaps in the asteroid belt . In the region between 40 and 42 AU , for instance , no objects can retain a stable orbit over such times , and any observed in that region must have migrated there relatively recently .

= = = Classical belt = = =

Between the 2 : 3 and 1 : 2 resonances with Neptune , at approximately 42 ? 48 AU , the gravitational influence of Neptune is negligible , and objects can exist with their orbits essentially unaltered . This region is known as the classical Kuiper belt , and its members comprise roughly two thirds of KBOs observed to date . Because the first modern KBO discovered , ( 15760 ) 1992 QB1 , is considered the prototype of this group , classical KBOs are often referred to as cubewanos ( " Q @-@ B @-@ 1 @-@ os " ) . The guidelines established by the IAU demand that classical KBOs be given names of mythological beings associated with creation .

The classical Kuiper belt appears to be a composite of two separate populations . The first , known as the " dynamically cold " population , has orbits much like the planets ; nearly circular , with an orbital eccentricity of less than 0 @.@ 1 , and with relatively low inclinations up to about 10 ° ( they lie close to the plane of the Solar System rather than at an angle ) . The cold population also contain a concentration of objects , referred to as the kernel , with semi @-@ major axes at 44 ? 44 @.@ 5 AU . The second , the " dynamically hot " population , has orbits much more inclined to the ecliptic , by up to 30 ° . The two populations have been named this way not because of any major difference in temperature , but from analogy to particles in a gas , which increase their relative velocity as they become heated up . Not only are the two populations in different orbits , the cold population also differs in color and albedo , being redder and brighter , has a larger fraction of binary objects , has a different size distribution , and lacks very large objects . The difference in colors may be a reflection of different compositions , which suggests they formed in different regions . The hot population is proposed to have formed near Jupiter , and to have been ejected out by movements among the giant planets . The cold population , on the other hand , has been proposed to have formed more or less in its current position . Although it has been suggested that the cold population was also swept outwards by Neptune during its migration , particularly if Neptune 's eccentricity was transiently increased , the loose binaries among the cold population are unlikely to survive encounters with Neptune during this migration . Although the Nice model appears to be able to at least partially explain a compositional difference , it has also been suggested the color difference may reflect differences in surface evolution .

= = = Resonances = = =

When an object 's orbital period is an exact ratio of Neptune 's ( a situation called a mean @-@ motion resonance ) , then it can become locked in a synchronised motion with Neptune and avoid being perturbed away if their relative alignments are appropriate . If , for instance , an object orbits the Sun twice for every three Neptune orbits , and if it reaches perihelion with Neptune a quarter of an orbit away from it , then whenever it returns to perihelion , Neptune will always be in about the same relative position as it began , because it will have completed 1 1 ? 2 orbits in the same time . This is known as the 2 : 3 ( or 3 : 2 ) resonance , and it corresponds to a characteristic semi @-@ major axis of about 39 @.@ 4 AU . This 2 : 3 resonance is populated by about 200 known objects , including Pluto together with its moons . In recognition of this , the members of this family are known as plutinos . Many plutinos , including Pluto , have orbits that cross that of Neptune , though their resonance means they can never collide . Plutinos have high orbital eccentricities , suggesting that they are not native to their current positions but were instead thrown haphazardly into their orbits by the migrating Neptune . IAU guidelines dictate that all plutinos must , like Pluto , be named for underworld deities . The 1 : 2 resonance ( whose objects complete half an orbit for each of Neptune 's ) corresponds to semi @-@ major axes of ~ 47.7AU , and is sparsely populated . Its residents are sometimes referred to as twotinos . Other resonances also exist at 3 : 4 , 3 : 5 , 4 : 7 and 2 : 5 . Neptune has a number of trojan objects , which occupy its Lagrangian points , gravitationally stable regions leading and trailing it in its orbit . Neptune trojans are in a 1 : 1 mean @-@ motion resonance with Neptune and often have very stable orbits .

Additionally , there is a relative absence of objects with semi @-@ major axes below 39 AU that cannot apparently be explained by the present resonances . The currently accepted hypothesis for the cause of this is that as Neptune migrated outward , unstable orbital resonances moved gradually through this region , and thus any objects within it were swept up , or gravitationally ejected from it .

= = = " Kuiper cliff " = = =

The 1 : 2 resonance appears to be an edge beyond which few objects are known . It is not clear whether it is actually the outer edge of the classical belt or just the beginning of a broad gap . Objects have been detected at the 2 : 5 resonance at roughly 55 AU , well outside the classical belt ; however , predictions of a large number of bodies in classical orbits between these resonances have not been verified through observation .

Based on estimations of the primordial mass required to form Uranus and Neptune , as well as bodies as large as Pluto ( see below ) , earlier models of the Kuiper belt had suggested that the number of large objects would increase by a factor of two beyond 50 AU , so this sudden drastic falloff , known as the " Kuiper cliff " , was completely unexpected , and its cause , to date , is unknown . In 2003 , Bernstein and Trilling et al. found evidence that the rapid decline in objects of 100 km or more in radius beyond 50 AU is real , and not due to observational bias . Possible explanations include that material at that distance was too scarce or too scattered to accrete into large objects , or that subsequent processes removed or destroyed those that did . Patryk Lykawka of Kobe University has claimed that the gravitational attraction of an unseen large planetary object , perhaps the size of Earth or Mars , might be responsible .

= = Origin = =

The precise origins of the Kuiper belt and its complex structure are still unclear , and astronomers are awaiting the completion of several wide @-@ field survey telescopes such as Pan @-@ STARRS and the future LSST , which should reveal many currently unknown KBOs . These surveys will provide data that will help determine answers to these questions .

The Kuiper belt is thought to consist of planetesimals , fragments from the original protoplanetary disc around the Sun that failed to fully coalesce into planets and instead formed into smaller bodies , the largest less than 3 @,@ 000 kilometres ( 1 @,@ 900 mi ) in diameter . Studies of the crater counts on Pluto and Charon suggest that such objects formed directly as sizeable objects in the range of tens of kilometers in diameter rather than being accreted from much smaller , roughly kilometer scale bodies . Hypothetical mechanisms for the formation of these larger bodies include the gravitational collapse of clouds of pebbles concentrated between eddies in a turbulent protoplanetary disk or in streaming instabilities . These collapsing clouds may fragment , forming binaries .

Modern computer simulations show the Kuiper belt to have been strongly influenced by Jupiter and Neptune , and also suggest that neither Uranus nor Neptune could have formed in their present positions , because too little primordial matter existed at that range to produce objects of such high mass . Instead , these planets are estimated to have formed closer to Jupiter . Scattering of planetesimals early in the Solar System 's history would have led to migration of the orbits of the giant planets : Saturn , Uranus , and Neptune drifted outwards , whereas Jupiter drifted inwards . Eventually , the orbits shifted to the point where Jupiter and Saturn reached an exact 2 : 1 resonance ; Jupiter orbited the Sun twice for every one Saturn orbit . The gravitational repercussions of such a resonance ultimately destabilized the orbits of Uranus and Neptune , causing them to be scattered outward onto high @-@ eccentricity orbits that crossed the primordial planetesimal disc . While Neptune 's orbit was highly eccentric , its mean @-@ motion resonances overlapped and the orbits of the planetesimals evolved chaotically , allowing planetesimals to wander outward as far as Neptune 's 2 : 1 resonance to form a dynamically cold belt of low @-@ inclination objects . Later , after its eccentricity decreased , Neptune 's orbit expanded outward toward its current position . Many planetesimals were captured into and remain in resonances during this migration , others evolved onto higher @-@ inclination and lower @-@ eccentricity orbits and escaped from the resonances onto stable orbits . Many more planetesimals were scattered inward , with small fractions being captured as Jupiter trojans , as irregular satellites orbiting the giant planets , and as outer belt asteroids . The remainder were scattered outward again by Jupiter and in most cases ejected from the Solar System reducing the primordial Kuiper belt population by 99 % or more .

While the original version of the currently most popular model , the " Nice model " , reproduces many characteristics of the Kuiper belt such as the " cold " and " hot " populations , resonant objects , and a scattered disc , it still fails to account for some of the characteristics of their distributions . The model predicts a higher average eccentricity in classical KBO orbits than is observed ( 0 @.@ 10 ? 0 @.@ 13 versus 0 @.@ 07 ) and its predicted inclination distribution contains too few high inclination objects . In addition , the frequency of binary objects in the cold belt , many of which are far apart and loosely bound , also poses a problem for the model . These are predicted to have been separated during encounters with Neptune , leading some to propose that the cold disc formed at its current location .

A recent modification of the Nice model has the Solar System begin with five giant planets , including an additional ice giant , in a chain of mean @-@ motion resonances . About 400 million years after the formation of the Solar System the resonance chain is broken . Instead of being scattered into the disc , the ice giants first migrate outward several AU . This divergent migration eventually leads to a resonance crossing , destabilizing the orbits of the planets . The extra ice giant encounters Saturn and is scattered inward onto a Jupiter @-@ crossing orbit and after a series of encounters is ejected from the Solar System . The remaining planets then continue their migration until the planetesimal disc in nearly depleted with small fractions remaining in various locations .

As in the original Nice model , objects are captured into resonances with Neptune during its outward migration . Some remain in the resonances , others evolve onto higher @-@ inclination , lower @-@ eccentricity orbits , and are released onto stable orbits forming the dynamically hot classical belt . The hot belt 's inclination distribution can be reproduced if Neptune migrated from 24 AU to 30 AU on a 30 Myr timescale . When Neptune migrates to 28 AU , it has a gravitational encounter with the extra ice giant . Objects captured from the cold belt into the 2 : 1 mean @-@ motion resonance with Neptune are left behind as a local concentration at 44 AU when this encounter causes Neptune 's semi @-@ major axis to jump outward . If Neptune 's eccentricity remains small during this encounter the chaotic evolution of orbits of the original Nice model is avoided and a primordial cold belt is preserved . In the later phases of Neptune 's migration a slow sweeping of mean @-@ motion resonances removes the higher @-@ eccentricity objects from the cold belt truncating its eccentricity distribution .

= = Composition = =

Being distant from the Sun and major planets , Kuiper belt objects are thought to be relatively unaffected by the processes that have shaped and altered other Solar System objects ; thus , determining their composition would provide substantial information on the makeup of the earliest Solar System . However , due to their small size and extreme distance from Earth , the chemical makeup of KBOs is very difficult to determine . The principal method by which astronomers determine the composition of a celestial object is spectroscopy . When an object 's light is broken into its component colors , an image akin to a rainbow is formed . This image is called a spectrum . Different substances absorb light at different wavelengths , and when the spectrum for a specific object is unravelled , dark lines ( called absorption lines ) appear where the substances within it have absorbed that particular wavelength of light . Every element or compound has its own unique spectroscopic signature , and by reading an object 's full spectral " fingerprint " , astronomers can determine what it is made of .

Analysis indicates that Kuiper belt objects are composed of a mixture of rock and a variety of ices such as water , methane , and ammonia . The temperature of the belt is only about 50 K , so many compounds that would be gaseous closer to the Sun remain solid . The densities and rock ? ice fractions are known for only a small number of objects for which the diameters and the masses have been determined . The diameter can be determined by imaging with a high @-@ resolution telescope such as the Hubble Space Telescope , by the timing of an occultation when an object passes in front of a star , or , most commonly , by using the albedo of an object calculated from its infrared emissions . The masses are determined using the semi @-@ major axes and periods of satellites , which are therefore known only for a few binary objects . The densities range from less than 0 @.@ 4 to 2 @.@ 6 g / cm3 . The least dense objects are thought to be largely composed of ice and have significant porosity . The densest objects are likely composed of rock with a thin crust of ice . There is a trend of low densities for small objects and high densities for the largest objects . One possible explanation for this trend is that ice was lost from the surface layers when differentiated objects collided to form the largest objects .

Initially , detailed analysis of KBOs was impossible , and so astronomers were only able to determine the most basic facts about their makeup , primarily their color . These first data showed a broad range of colors among KBOs , ranging from neutral grey to deep red . This suggested that their surfaces were composed of a wide range of compounds , from dirty ices to hydrocarbons . This diversity was startling , as astronomers had expected KBOs to be uniformly dark , having lost most of the volatile ices from their surfaces to the effects of cosmic rays . Various solutions were suggested for this discrepancy , including resurfacing by impacts or outgassing . However , Jewitt and Luu 's spectral analysis of the known Kuiper belt objects in 2001 found that the variation in color was too extreme to be easily explained by random impacts . The radiation from the Sun is thought to have chemically altered methane on the surface of KBOs , producing products such as tholins . Makemake has been shown to possess a number of hydrocarbons derived from the radiation @-@ processing of methane , including ethane , ethylene and acetylene .

Although to date most KBOs still appear spectrally featureless due to their faintness , there have been a number of successes in determining their composition . In 1996 , Robert H. Brown et al. acquired spectroscopic data on the KBO 1993 SC , which revealed that its surface composition is markedly similar to that of Pluto , as well as Neptune 's moon Triton , with large amounts of methane ice . For the smaller objects only colors and in some cases the albedos have been determined . These objects largely fall into two classes : gray with low albedos , or very red with higher albedos . The difference in colors and albedos is hypothesized to be due to the retention or the loss of hydrogen sulfide ( H2S ) on the surface of these objects , with the surfaces of those that formed far enough from the Sun to retain H2S being reddened due to irradiation .

The largest KBOs , such as Pluto and Quaoar , have surfaces rich in volatile compounds such as methane , nitrogen and carbon monoxide ; the presence of these molecules is likely due to their moderate vapor pressure in the 30 ? 50 K temperature range of the Kuiper belt . This allows them to occasionally boil off their surfaces and then fall again as snow , whereas compounds with higher boiling points would remain solid . The relative abundances of these three compounds in the largest KBOs is directly related to their surface gravity and ambient temperature , which determines which they can retain . Water ice has been detected in several KBOs , including members of the Haumea family such as 1996 TO66 , mid @-@ sized objects such as 38628 Huya and 20000 Varuna , and also on some small objects . The presence of crystalline ice on large and mid @-@ sized objects , including 50000 Quaoar where ammonia hydrate has also been detected , may indicate past tectonic activity aided by melting point lowering due to the presence of ammonia .

= = Mass and size distribution = =

Despite its vast extent , the collective mass of the Kuiper belt is relatively low . The total mass is estimated to range between 1 / 25th and 1 / 10th the mass of the Earth . Conversely , models of the Solar System 's formation predict a collective mass for the Kuiper belt of 30 Earth masses . This missing > 99 % of the mass can hardly be dismissed , because it is required for the accretion of any KBOs larger than 100 km ( 62 mi ) in diameter . If the Kuiper belt had always had its current low density these large objects simply could not have formed by the collision and mergers of smaller planetesimals . Moreover , the eccentricity and inclination of current orbits makes the encounters quite " violent " resulting in destruction rather than accretion . It appears that either the current residents of the Kuiper belt have been created closer to the Sun or some mechanism dispersed the original mass . Neptune 's current influence is too weak to explain such a massive " vacuuming " , though the Nice model proposes that it could have been the cause of mass removal in the past . Although the question remains open , the conjectures vary from a passing star scenario to grinding of smaller objects , via collisions , into dust small enough to be affected by solar radiation . The extent of mass loss by collisional grinding , however , is limited by the presence of loosely bound binaries in the cold disk , which are likely to be disrupted in collisions .

Bright objects are rare compared with the dominant dim population , as expected from accretion models of origin , given that only some objects of a given size would have grown further . This relationship between N ( D ) ( the number of objects of diameter greater than D ) and D , referred to as brightness slope , has been confirmed by observations . The slope is inversely proportional to some power of the diameter D :

<formula> where the current measures give q = 4 ± 0 @.@ 5 .

This implies ( assuming q is not 1 ) that

<formula>

( The constant may be non @-@ zero only if the power law doesn 't apply at high values of D. )

Less formally , if q is 4 , for example , there are 8 ( = 23 ) times more objects in the 100 ? 200 km range than in the 200 ? 400 km range , and for every object with a diameter between 1000 and 1010 km there should be around 1000 ( = 103 ) objects with diameter of 100 to 101 km .

If q is 1 or less , the law implies an infinite number and mass of large objects in the Kuiper belt . If 1 < q ? 4 there will be a finite number of objects greater than a given size , but the expected value of their combined mass would be infinite . If q is 4 or more , the law would imply an infinite mass of small objects . More accurate models find that the " slope " parameter q is in effect greater at large diameters and lesser at small diameters . It seems that Pluto is somewhat unexpectedly large , having several percent of the total mass of the Kuiper belt . It is not expected that anything larger than Pluto exists in the Kuiper belt , and in fact most of the brightest ( largest ) objects at inclinations less than 5 ° have probably been found .

Of course , only the absolute magnitude is actually known , the size is inferred assuming a given albedo ( not a safe assumption for larger objects ) .