

= Scattered disc =

The scattered disc ( or scattered disk ) is a distant circumstellar disc in the Solar System that is sparsely populated by icy minor planets , a subset of the broader family of trans -Neptunian objects . The scattered -disc objects ( SDOs ) have orbital eccentricities ranging as high as 0.8 , inclinations as high as 40 ° , and perihelia greater than 30 astronomical units ( 40 - 50 × 10<sup>9</sup> km ; 20 - 30 × 10<sup>9</sup> mi ) . These extreme orbits are thought to be the result of gravitational " scattering " by the gas giants , and the objects continue to be subject to perturbation by the planet Neptune .

Although the closest scattered -disc objects approach the Sun at about 30 - 35 AU , their orbits can extend well beyond 100 AU . This makes scattered objects among the most distant and coldest objects in the Solar System . The innermost portion of the scattered disc overlaps with a torus -shaped region of orbiting objects traditionally called the Kuiper belt , but its outer limits reach much further away from the Sun and further above and below the ecliptic than the Kuiper belt proper .

Because of its unstable nature , astronomers now consider the scattered disc to be the place of origin for most periodic comets in the Solar System , with the centaurs , a population of icy bodies between Jupiter and Neptune , being the intermediate stage in an object 's migration from the disc to the inner Solar System . Eventually , perturbations from the giant planets send such objects towards the Sun , transforming them into periodic comets . Many Oort cloud objects are also thought to have originated in the scattered disc . Detached objects are not sharply distinct from scattered disc objects , and some such as Sedna have sometimes been considered to be included in this group .

= = Discovery = =

Traditionally , devices like a blink comparator were used in astronomy to detect objects in the Solar System , because these objects would move between two exposures - this involved time -consuming steps like exposing and developing photographic plates or films , and people then using a blink comparator to manually detect prospective objects . During the 1980s , the use of CCD -based cameras in telescopes made it possible to directly produce electronic images that could then be readily digitized and transferred to digital images . Because the CCD captured more light than film ( about 90 % versus 10 % of incoming light ) and the blinking could now be done at an adjustable computer screen , the surveys allowed for higher throughput . A flood of new discoveries was the result : over a thousand trans -Neptunian objects were detected between 1992 and 2006 .

The first scattered -disc object ( SDO ) to be recognised as such was 1996 TL<sub>66</sub> , originally identified in 1996 by astronomers based at Mauna Kea in Hawaii . Three more were identified by the same survey in 1999 : 1999 CV<sub>118</sub> , 1999 CY<sub>118</sub> , and 1999 CF<sub>119</sub> . The first object presently classified as an SDO to be discovered was 1995 TL<sub>8</sub> , found in 1995 by Spacewatch .

As of 2011 , over 200 SDOs have been identified , including 2007 UK<sub>126</sub> ( discovered by Schwamb , Brown , and Rabinowitz ) , 2002 TC<sub>302</sub> ( NEAT ) , Eris ( Brown , Trujillo , and Rabinowitz ) , Sedna ( Brown , Trujillo , and Rabinowitz ) and 2004 VN<sub>112</sub> ( Deep Ecliptic Survey ) . Although the numbers of objects in the Kuiper belt and the scattered disc are hypothesized to be roughly equal , observational bias due to their greater distance means that far fewer SDOs have been observed to date .

= = Subdivisions of trans -Neptunian space = =

Known trans -Neptunian objects are often divided into two subpopulations : the Kuiper belt and the scattered disc . A third reservoir of trans -Neptunian objects , the Oort cloud , has been hypothesized , although no confirmed direct observations of the Oort cloud have been made . Some researchers further suggest a transitional space between the scattered disc and the inner Oort cloud , populated with " detached objects " .

## == Scattered disc versus Kuiper belt ==

The Kuiper belt is a relatively thick torus ( or " doughnut " ) of space , extending from about 30 to 50 AU comprising two main populations of Kuiper belt objects ( KBOs ) : the classical Kuiper @-@ belt objects ( or " cubewanos " ) , which lie in orbits untouched by Neptune , and the resonant Kuiper @-@ belt objects ; those which Neptune has locked into a precise orbital ratio such as 3 : 2 ( the object goes around twice for every three Neptune orbits ) and 2 : 1 ( the object goes around once for every two Neptune orbits ) . These ratios , called orbital resonances , allow KBOs to persist in regions which Neptune 's gravitational influence would otherwise have cleared out over the age of the Solar System , since the objects are never close enough to Neptune to be scattered by its gravity . Those in 3 : 2 resonances are known as " plutinos " , because Pluto is the largest member of their group , whereas those in 2 : 1 resonances are known as " twotinos " .

In contrast to the Kuiper belt , the scattered @-@ disc population can be disturbed by Neptune . Scattered @-@ disc objects come within gravitational range of Neptune at their closest approaches ( ~ 30 AU ) but their farthest distances reach many times that . Ongoing research suggests that the centaurs , a class of icy planetoids that orbit between Jupiter and Neptune , may simply be SDOs thrown into the inner reaches of the Solar System by Neptune , making them " cis @-@ Neptunian " rather than trans @-@ Neptunian scattered objects . Some objects , like ( 29981 ) 1999 TD10 , blur the distinction and the Minor Planet Center ( MPC ) , which officially catalogues all trans @-@ Neptunian objects , now lists centaurs and SDOs together .

The MPC also makes a clear distinction between the Kuiper belt and the scattered disc ; separating those objects in stable orbits ( the Kuiper belt ) from those in scattered orbits ( the scattered disc and the centaurs ) . However , the difference between the Kuiper belt and the scattered disc is not clearcut , and many astronomy see the scattered disc not as a separate population but as an outward region of the Kuiper belt . Another term used is " scattered Kuiper @-@ belt object " ( or SKBO ) for bodies of the scattered disc .

Morbidelli and Brown propose that the difference between objects in the Kuiper @-@ belt and scattered @-@ disc objects is that the latter bodies " are transported in semi @-@ major axis by close and distant encounters with Neptune " , but the former experienced no such close encounters . This delineation is inadequate ( as they note ) over the age of the Solar System , since bodies " trapped in resonances " could " pass from a scattering phase to a non @-@ scattering phase ( and vice versa ) numerous times " . That is , trans @-@ Neptunian objects could travel back and forth between the Kuiper belt and the scattered disc over time . Therefore , they chose instead to define the regions , rather than the objects , defining the scattered disc as " the region of orbital space that can be visited by bodies that have encountered Neptune " within the radius of a Hill sphere , and the Kuiper belt as its " complement ... in the  $a > 30$  AU region " ; the region of the Solar System populated by objects with semi @-@ major axes greater than 30 AU .

## == Detached objects ==

The Minor Planet Center classifies the trans @-@ Neptunian object 90377 Sedna as a scattered @-@ disc object . Its discoverer Michael E. Brown has suggested instead that it should be considered an inner Oort @-@ cloud object rather than a member of the scattered disc , because , with a perihelion distance of 76 AU , it is too remote to be affected by the gravitational attraction of the outer planets . Under this definition , an object with a perihelion greater than 40 AU could be classified as outside the scattered disc .

Sedna is not the only such object : 2000 CR105 ( discovered before Sedna ) and 2004 VN112 have a perihelion too far away from Neptune to be influenced by it . This led to a discussion among astronomers about a new minor planet set , called the extended scattered disc ( E @-@ SDO ) . 2000 CR105 may also be an inner Oort @-@ cloud object or ( more likely ) a transitional object between the scattered disc and the inner Oort cloud . More recently , these objects have been referred to as " detached " , or distant detached objects ( DDO ) .

There are no clear boundaries between the scattered and detached regions . Gomes et al. define SDOs as having " highly eccentric orbits , perihelia beyond Neptune , and semi @-@ major axes beyond the 1 : 2 resonance . " By this definition , all distant detached objects are SDOs . Since detached objects ' orbits cannot be produced by Neptune scattering , alternative scattering mechanisms have been put forward , including a passing star or a distant , planet @-@ sized object .

A scheme introduced by a 2005 report from the Deep Ecliptic Survey by J. L. Elliott et al. distinguishes between two categories : scattered @-@ near ( i.e. typical SDOs ) and scattered @-@ extended ( i.e. detached objects ) . Scattered @-@ near objects are those whose orbits are non @-@ resonant , non @-@ planetary @-@ orbit @-@ crossing and have a Tisserand parameter ( relative to Neptune ) less than 3 . Scattered @-@ extended objects have a Tisserand parameter ( relative to Neptune ) greater than 3 and have a time @-@ averaged eccentricity greater than 0 @-@ 2 .

An alternative classification , introduced by B. J. Gladman , B. G. Marsden and C. Van Laerhoven in 2007 , uses 10 @-@ million @-@ year orbit integration instead of the Tisserand parameter . An object qualifies as an SDO if its orbit is not resonant , has a semi @-@ major axis no greater than 2000 AU , and , during the integration , its semi @-@ major axis shows an excursion of 1 @-@ 5 AU or more . Gladman et al. suggest the term scattering disk object to emphasize this present mobility . If the object is not an SDO as per the above definition , but the eccentricity of its orbit is greater than 0 @-@ 240 , it is classified as a detached TNO . ( Objects with smaller eccentricity are considered classical . ) In this scheme , the disc extends from the orbit of Neptune to 2000 AU , the region referred to as the inner Oort cloud .

= = Orbits = =

The scattered disc is a very dynamic environment . Because they are still capable of being perturbed by Neptune , SDOs ' orbits are always in danger of disruption ; either of being sent outward to the Oort cloud or inward into the centaur population and ultimately the Jupiter family of comets . For this reason Gladman et al. prefer to refer to the region as the scattering disc , rather than scattered . Unlike Kuiper @-@ belt objects ( KBOs ) , the orbits of scattered @-@ disc objects can be inclined as much as 40 ° from the ecliptic .

SDOs are typically characterized by orbits with medium and high eccentricities with a semi @-@ major axis greater than 50 AU , but their perihelia bring them within influence of Neptune . Having a perihelion of roughly 30 AU is one of the defining characteristics of scattered objects , as it allows Neptune to exert its gravitational influence .

The classical objects ( cubewanos ) are very different from the scattered objects : more than 30 % of all cubewanos are on low @-@ inclination , near @-@ circular orbits whose eccentricities peak at 0 @-@ 25 . Classical objects possess eccentricities ranging from 0 @-@ 2 to 0 @-@ 8 . Though the inclinations of scattered objects are similar to the more extreme KBOs , very few scattered objects have orbits as close to the ecliptic as much of the KBO population .

Although motions in the scattered disc are random , they do tend to follow similar directions , which means that SDOs can become trapped in temporary resonances with Neptune . Examples of resonant orbits within the scattered disc include 1 : 3 , 2 : 7 , 3 : 11 , 5 : 22 and 4 : 79 .

= = Formation = =

The scattered disc is still poorly understood : no model of the formation of the Kuiper belt and the scattered disc has yet been proposed that explains all their observed properties .

According to contemporary models , the scattered disc formed when Kuiper belt objects ( KBOs ) were " scattered " into eccentric and inclined orbits by gravitational interaction with Neptune and the other outer planets . The amount of time for this process to occur remains uncertain . One hypothesis estimates a period equal to the entire age of the Solar System ; a second posits that the scattering took place relatively quickly , during Neptune 's early migration epoch .

Models for a continuous formation throughout the age of the Solar System illustrate that at weak resonances within the Kuiper belt ( such as 5 : 7 or 8 : 1 ) , or at the boundaries of stronger resonances , objects can develop weak orbital instabilities over millions of years . The 4 : 7 resonance in particular has large instability . KBOs can also be shifted into unstable orbits by close passage of massive objects , or through collisions . Over time , the scattered disc would gradually form from these isolated events .

Computer simulations have also suggested a more rapid and earlier formation for the scattered disc . Modern theories indicate that neither Uranus nor Neptune could have formed in situ beyond Saturn , as too little primordial matter existed at that range to produce objects of such high mass . Instead , these planets , and Saturn , may have formed closer to Jupiter , but were flung outwards during the early evolution of the Solar System , perhaps through exchanges of angular momentum with scattered objects . Once the orbits of Jupiter and Saturn shifted to a 2 : 1 resonance ( two Jupiter orbits for each orbit of Saturn ) , their combined gravitational pull disrupted the orbits of Uranus and Neptune , sending Neptune into the temporary " chaos " of the proto @-@ Kuiper belt . As Neptune traveled outward , it scattered many trans @-@ Neptunian objects into higher and more eccentric orbits . This model states that 90 % or more of the objects in the scattered disc may have been " promoted into these eccentric orbits by Neptune 's resonances during the migration epoch ... [ therefore ] the scattered disc might not be so scattered . "

= = Composition = =

Scattered objects , like other trans @-@ Neptunian objects , have low densities and are composed largely of frozen volatiles such as water and methane . Spectral analysis of selected Kuiper belt and scattered objects has revealed signatures of similar compounds . Both Pluto and Eris , for instance , show signatures for methane .

Astronomers originally supposed that the entire trans @-@ Neptunian population would show a similar red surface colour , as they were thought to have originated in the same region and subjected to the same physical processes . Specifically , SDOs were expected to have large amounts of surface methane , chemically altered into complex organic molecules by energy from the Sun . This would absorb blue light , creating a reddish hue . Most classical objects display this colour , but scattered objects do not ; instead , they present a white or greyish appearance .

One explanation is the exposure of whiter subsurface layers by impacts ; another is that the scattered objects ' greater distance from the Sun creates a composition gradient , analogous to the composition gradient of the terrestrial and gas giant planets . Mike Brown , discoverer of the scattered object Eris , suggests that its paler colour could be because , at its current distance from the Sun , its atmosphere of methane is frozen over its entire surface , creating an inches @-@ thick layer of bright white ice . Pluto , conversely , being closer to the Sun , would be warm enough that methane would freeze only onto cooler , high @-@ albedo regions , leaving low @-@ albedo tholin @-@ covered regions bare of ice .

= = Comets = =

The Kuiper belt was initially thought to be the source of the Solar System 's ecliptic comets . However , studies of the region since 1992 have shown that the orbits within the Kuiper belt are relatively stable , and that these comets originate from the scattered disc , where orbits are generally less stable .

Comets can loosely be divided into two categories : short @-@ period and long @-@ period ? the latter being thought to originate in the Oort cloud . The two major categories of short @-@ period comets are Jupiter @-@ family comets ( JFCs ) and Halley @-@ type comets . Halley @-@ type comets , which are named after their prototype , Halley 's Comet , are thought to have originated in the Oort cloud but to have been drawn into the inner Solar System by the gravity of the giant planets , whereas the JFCs are thought to have originated in the scattered disc . The centaurs are thought to be a dynamically intermediate stage between the scattered disc and the Jupiter family .

There are many differences between SDOs and JFCs , even though many of the Jupiter @-@ family comets may have originated in the scattered disc . Although the centaurs share a reddish or neutral coloration with many SDOs , their nuclei are bluer , indicating a fundamental chemical or physical difference . One hypothesis is that comet nuclei are resurfaced as they approach the Sun by subsurface materials which subsequently bury the older material .