= Dyson sphere =

A Dyson sphere is a hypothetical megastructure that completely encompasses a star and captures most or all of its power output . The concept was first described by Olaf Stapledon in his science fiction novel , Star Maker (1937) , and later popularized by Freeman Dyson in his 1960 paper , " Search for Artificial Stellar Sources of Infrared Radiation " . Dyson speculated that such structures would be the logical consequence of the escalating energy needs of a technological civilization and would be a necessity for its long @-@ term survival . He proposed that searching for such structures could lead to the detection of advanced , intelligent extraterrestrial life . Different types of Dyson spheres and their energy @-@ harvesting ability would correspond to levels of technological advancement on the Kardashev scale .

Since then , other variant designs involving building an artificial structure or series of structures to encompass a star have been proposed in exploratory engineering or described in science fiction under the name " Dyson sphere " . These later proposals have not been limited to solar @-@ power stations , with many involving habitation or industrial elements . Most fictional depictions describe a solid shell of matter enclosing a star , which is considered the least plausible variant of the idea . In May 2013 , at the Starship Century Symposium in San Diego , Dyson repeated his comments that he wished the concept had not been named after him .

= = Origin of concept = =

The concept of the Dyson sphere was the result of a thought experiment by physicist and mathematician Freeman Dyson , when he theorized that all technological civilizations constantly increased their demand for energy . He reasoned that if human civilization expanded energy demands long enough , there would come a time when it demanded the total energy output of the Sun . He proposed a system of orbiting structures (which he referred to initially as a shell) designed to intercept and collect all energy produced by the Sun . Dyson 's proposal did not detail how such a system would be constructed , but focused only on issues of energy collection , on the basis that such a structure could be distinguished by its unusual emission spectrum in comparison to a star . His 1960 paper " Search for Artificial Stellar Sources of Infra @-@ Red Radiation " , published in the journal Science , is credited with being the first to formalize the concept of the Dyson sphere .

However , Dyson was not the first to advance this idea . He was inspired by the mention of the concept in the 1937 science fiction novel Star Maker , by Olaf Stapledon , and possibly by the works of J. D. Bernal , Raymond Z. Gallun , and Edgar Rice Burroughs who seem to have explored similar concepts in their work .

= = Feasibility = =

Although such megastructures may be theoretically possible , all plans to build a fixed @-@ in @-@ place Dyson sphere are currently far beyond humanity 's engineering capacity . However , parts of the technology , like orbiting satellites and solar sails , have already been developed . Deployment of spacecraft and satellites using photovoltaics might be seen as the first small steps towards building a Dyson swarm . However , the number of craft required to obtain , transmit , and maintain a complete Dyson sphere far exceeds present @-@ day industrial capabilities . George Dvorsky has advocated use of self @-@ replicating robots to overcome this limitation in the relatively near term . Some have suggested that such habitats could be built around white dwarfs and even pulsars .

= = Variants = =

In fictional accounts , the Dyson @-@ sphere concept is often interpreted as an artificial hollow sphere of matter around a star . This perception is based on a literal interpretation of Dyson 's original short paper introducing the concept . In response to letters prompted by this paper , Dyson

replied , " A solid shell or ring surrounding a star is mechanically impossible . The form of ' biosphere ' which I envisaged consists of a loose collection or swarm of objects traveling on independent orbits around the star . "

= = = Dyson swarm = = =

The variant closest to Dyson 's original conception is the " Dyson swarm " . It consists of a large number of independent constructs (usually solar power satellites and space habitats) orbiting in a dense formation around the star . This construction approach has advantages : components could be sized appropriately , and it can be constructed incrementally . Various forms of wireless energy transfer could be used to transfer energy between components and Earth .

Disadvantages resulting from the nature of orbital mechanics would make the arrangement of the orbits of the swarm extremely complex . The simplest such arrangement is the Dyson ring , in which all such structures share the same orbit . More @-@ complex patterns with more rings would intercept more of the star 's output , but would result in some constructs eclipsing others periodically when their orbits overlap . Another potential problem is the increasing loss of orbital stability when adding more elements increases the probability of orbital perturbations .

As noted below , such a cloud of collectors would alter the light emitted by the star system . However , the disruption compared to a star 's overall natural emitted spectrum would most likely be too small to be noticed on Earth .

= = = Dyson bubble = = =

A second type of Dyson sphere is the " Dyson bubble " . It would be similar to a Dyson swarm , composed of many independent constructs (usually solar power satellites and space habitats) and likewise could be constructed incrementally .

Unlike the Dyson swarm , the constructs making it up are not in orbit around the star , but would be statites ? satellites suspended by use of enormous light sails using radiation pressure to counteract the star 's pull of gravity . Such constructs would not be in danger of collision or of eclipsing one another ; they would be totally stationary with regard to the star , and independent of one another . Because the ratio of radiation pressure and the force of gravity from a star is constant regardless of the distance (provided the statite has an unobstructed line @-@ of @-@ sight to the surface of its star) , such statites could also vary their distance from their central star .

The practicality of this approach is questionable with modern material science , but cannot yet be ruled out . A 100 % reflective statite deployed around the Sun would have an overall density of 0 @.@ 78 grams per square meter of sail . To illustrate the low mass of the required materials , consider that the total mass of a bubble of such material 1 AU in radius would be about 2 @.@ 17 × 1020 kg , which is about the same mass as the asteroid Pallas . Another illustration : Regular printing paper has a density of around 80 g / m2 .

Such a material has not yet been produced in the form of a working light sail . The lightest carbon @-@ fiber light @-@ sail material currently produced has a density ? without payload ? of 3 g / m2 , or about four times as heavy as would be needed to construct a solar statite .

A single sheet of graphene , the two @-@ dimensional form of carbon , has a density of only 0 @.@ 37 mg per square meter , making such a single sheet of graphene possibly effective as a solar sail . However , as of 2015 graphene has not been fabricated in large sheets , and it has a relatively high rate of radiation absorption , about 2 @.@ 3 % (i.e. , it would only be 97 @.@ 7 % reflective) . For frequencies in the upper GHz and lower THz range , the absorption rate is as high as 50 ? 100 % due to voltage bias and / or doping .

Ultra @-@ light carbon nanotubes meshed through molecular manufacturing techniques have densities between 1 @.@ 3 g / m2 to 1 @.@ 4 g / m2 . By the time a civilization is ready to use this technology , the carbon nanotube 's manufacturing might be optimised enough for them to have a density lower than the necessary 0 @.@ 7 g / m2 , and the average sail density with rigging might be kept to 0 @.@ 3 g / m2 (a " spin stabilized " light sail requires minimal additional mass in rigging

) . If such a sail could be constructed at this areal density , a space habitat the size of the L5 Society 's proposed O 'Neill cylinder ? 500 km2 , with room for over 1 million inhabitants , massing 3 × 106 tons ? could be supported by a circular light sail 3 @,@ 000 km in diameter , with a combined sail / habitat mass of 5 @.@ 4 × 109 kg . For comparison , this is just slightly smaller than the diameter of Jupiter 's moon Europa (although the sail is a flat disc , not a sphere) , or the distance between San Francisco and Kansas City . Such a structure would , however , have a mass quite a lot less than many asteroids . Although the construction of such a massive inhabitable statite would be a gigantic undertaking , and the required material science behind it is early stage , there are other engineering feats and required materials proposed in other Dyson sphere variants .

In theory , if enough statites were created and deployed around their star , they would compose a non @-@ rigid version of the Dyson shell mentioned below . Such a shell would not suffer from the drawbacks of massive compressive pressure , nor are the mass requirements of such a shell as high as the rigid form . Such a shell would , however , have the same optical and thermal properties as the rigid form , and would be detected by searchers in a similar fashion (see below) .

= = = Dyson shell = = =

The variant of the Dyson sphere most often depicted in fiction is the " Dyson shell " : a uniform solid shell of matter around the star . Such a structure would completely alter the emissions of the central star , and would intercept 100 % of the star 's energy output . Such a structure would also provide an immense surface that many envision would be used for habitation , if the surface could be made habitable .

A spherical shell Dyson sphere in the Solar System with a radius of one astronomical unit , so that the interior surface would receive the same amount of sunlight as Earth does per unit solid angle , would have a surface area of approximately 2 @.@ 8 × 1017 km2 (1 @.@ 1 × 1017 sq mi) , or about 550 million times the surface area of Earth . This would intercept the full 384 @.@ 6 yottawatts (3 @.@ 846 × 1026 watts) of the Sun 's output . Non @-@ shell designs would intercept less , but the shell variant represents the maximum possible energy captured for the Solar System at this point of the Sun 's evolution . This is approximately 33 trillion times the power consumption of humanity in 1998 , which was 12 terawatts .

There are several serious theoretical difficulties with the solid shell variant of the Dyson sphere :

Such a shell would have no net gravitational interaction with its englobed star (see shell theorem) , and could drift in relation to the central star . If such movements went uncorrected , they could eventually result in a collision between the sphere and the star ? most likely with disastrous results . Such structures would need either some form of propulsion to counteract any drift , or some way to repel the surface of the sphere away from the star .

For the same reason , such a shell would have no net gravitational interaction with anything else inside it . The contents of any biosphere placed on the inner surface of a Dyson shell would not be attracted to the sphere 's surface and would simply fall into the star . It has been proposed that a biosphere could be contained between two concentric spheres , placed on the interior of a rotating sphere (in which case , the force of artificial " gravity " is perpendicular to the axis of rotation , causing all matter placed on the interior of the sphere to pool around the equator , effectively rendering the sphere a Niven ring for purposes of habitation , but still fully effective as a radiant @-@ energy collector) or placed on the outside of the sphere where it would be held in place by the star 's gravity . In such cases , some form of illumination would have to be devised , or the sphere made at least partly transparent , because the star 's light would otherwise be completely hidden .

If assuming a radius of one AU , then the compressive strength of the material forming the sphere would have to be immense to prevent implosion due to the star 's gravity . Any arbitrarily selected point on the surface of the sphere can be viewed as being under the pressure of the base of a dome 1 AU in height under the Sun 's gravity at that distance . Indeed , it can be viewed as being at the base of an infinite number of arbitrarily selected domes , but because much of the force from any one arbitrary dome is counteracted by those of another , the net force on that point is immense , but finite . No known or theorized material is strong enough to withstand this pressure , and form a rigid ,

static sphere around a star . It has been proposed by Paul Birch (in relation to smaller " Supra @-@ Jupiter " constructions around a large planet rather than a star) that it may be possible to support a Dyson shell by dynamic means similar to those used in a space fountain . Masses travelling in circular tracks on the inside of the sphere , at velocities significantly greater than orbital velocity , would press outwards on magnetic bearings due to centrifugal force . For a Dyson shell of 1 @-@ AU radius around a star with the same mass as the Sun , a mass travelling ten times the orbital velocity (297 @.@ 9 km / s) would support 99 (a = v2 / r) times its own mass in additional shell structure .

Also if assuming a radius of one AU , then there may not be sufficient building material in the Solar System to construct a Dyson shell . Anders Sandberg estimates that there is 1 @.@ 82 × 1026 kg of easily usable building material in the Solar System , enough for a 1 @-@ AU shell with a mass of 600 kg / m2 ? about 8 ? 20 cm thick on average , depending on the density of the material . This includes the hard @-@ to @-@ access cores of the gas giants ; the inner planets alone provide only 11 @.@ 79 × 1024 kg , enough for a 1 @-@ AU shell with a mass of just 42 kg / m2 .

The shell would be vulnerable to impacts from interstellar bodies , such as comets , meteoroids , and material in interstellar space that is currently being deflected by the Sun 's bow shock . The heliosphere , and any protection it theoretically provides , would cease to exist .

= = = Other types = = =

= = = = Dyson net = = = =

Another possibility is the " Dyson net " , a web of cables strung about the star that could have power or heat collection units strung between the cables . The Dyson net reduces to a special case of Dyson shell or bubble , however , depending on how the cables are supported against the sun 's gravity .

= = = = Bubbleworld = = = =

A bubbleworld is an artificial construct that consists of a shell of living space around a sphere of hydrogen gas . The shell contains air , people , houses , furniture , etc . The idea was conceived to answer the question , " What is the largest space colony that can be built ? " However , most of the volume is not habitable and there is no power source .

Theoretically , any gas giant could be enclosed in a solid shell ; at a certain radius the surface gravity would be terrestrial , and energy could be provided by tapping the thermal energy of the planet . This concept is explored peripherally in the novel Accelerando (and the short story Curator , which is incorporated into the novel as a chapter) by Charles Stross , in which Saturn is converted into a human @-@ habitable world .

= = = = Stellar engine = = = =

Stellar engines are a class of hypothetical megastructures whose purpose is to extract useful energy from a star , sometimes for specific purposes . For example , Matrioshka brains extract energy for purposes of computation ; Shkadov thrusters extract energy for purposes of propulsion . Some of the proposed stellar engine designs are based on the Dyson sphere .

A black hole could be the power source instead of a star in order to increase the energy @-@ to @-@ matter conversion efficiency . A black hole would also be smaller than a star . This would decrease communication distances that would be important for computer @-@ based societies as those described above .

= = Search for megastructures = =

In Dyson 's original paper , he speculated that sufficiently advanced extraterrestrial civilizations would likely follow a similar power @-@ consumption pattern to that of humans , and would eventually build their own sphere of collectors . Constructing such a system would make such a civilization a Type II Kardashev civilization .

The existence of such a system of collectors would alter the light emitted from the star system . Collectors would absorb and reradiate energy from the star . The wavelength (s) of radiation emitted by the collectors would be determined by the emission spectra of the substances making them up , and the temperature of the collectors . Because it seems most likely that these collectors would be made up of heavy elements not normally found in the emission spectra of their central star ? or at least not radiating light at such relatively " low " energies compared to what they would be emitting as energetic free nuclei in the stellar atmosphere ? there would be atypical wavelengths of light for the star 's spectral type in the light spectrum emitted by the star system . If the percentage of the star 's output thus filtered or transformed by this absorption and reradiation was significant , it could be detected at interstellar distances .

Given the amount of energy available per square meter at a distance of 1 AU from the Sun , it is possible to calculate that most known substances would be reradiating energy in the infrared part of the electromagnetic spectrum . Thus , a Dyson sphere , constructed by life forms not dissimilar to humans , who dwelled in proximity to a Sun @-@ like star , made with materials similar to those available to humans , would most likely cause an increase in the amount of infrared radiation in the star system 's emitted spectrum . Hence , Dyson selected the title " Search for Artificial Stellar Sources of Infrared Radiation " for his published paper .

SETI has adopted these assumptions in their search , looking for such " infrared heavy " spectra from solar analogs . As of 2005 Fermilab has an ongoing survey for such spectra by analyzing data from the Infrared Astronomical Satellite (IRAS) . Identifying one of the many infrared sources as a Dyson sphere would require improved techniques for discriminating between a Dyson sphere and natural sources . Fermilab discovered 17 potential " ambiguous " candidates , of which four have been named " amusing but still questionable " . Other searches also resulted in several candidates , which are , however , unconfirmed .

On 14 October 2015 , the realization of a strange pattern of light from star KIC 8462852 , observed by the Kepler Space Telescope , raised speculation that a Dyson sphere may have been discovered .

= = Fiction = =

As noted above , the Dyson sphere originated in fiction , and it is a concept that has appeared often in science fiction since then . In fictional accounts , Dyson spheres are most often depicted as a Dyson shell with the gravitational and engineering difficulties of this variant noted above largely ignored .