Chapter 6

Teraworld

1 000 000 000 000 (1.0 x 10^{12}) T

6.1 Teraworld Length

1 – 1000 Terameters (Tm) 1 x 10^{12} m

List of Terameter Distant Objects

Example	Distance
Saturn	1.47 Tm
Uranus	2.87 Tm
Neptune	4.50 Tm
Pluto	7.40 Tm
Voyager 1	21.5 Tm
Comet Hale-Bopp Orbital Extent	55.7 Tm
Cosmic Telescope Focal Point	80 Tm
Oort Cloud's Extent	10 → 20 652 Tm

Table 6.1

The Terameter range of distances is a bit of an odd-man-out when it comes to astronomical distances. The Solar System is readily expressed in Gigameters (Gm), and distance to the nearest stars is in Petameters (Pm). Tera- is the only metric prefix left out of Table 1.1 which categorizes astronomical distances. Only

distances from our Sun to the outer planets approach Terameter lengths. When we reach Saturn (1.427 Tm) we enter Teraworld. Uranus (2.870 Tm) and Neptune (4.497 Tm) are not out of single digits. Gigameters are much more appropriate for Solar System dimensions. Even the dwarf planet Pluto, at the furthest extent of its orbit, is only 7.4 Terameters from the Sun. The Voyager 1 spacecraft is over 22 Terameters from the Sun in interstellar space, where only comets have roamed before. Comet Hale-Bopp was discovered in the Summer of 1995, and was visible to the unaided eye for 18 months. The maximum extent of its orbit is 55.7 Terameters. The tail of comet 153P/Ikeya-Zhang is thought to the longest known at about 1.12 Terameters.[1]

The idea of a black hole was first suggested in print by English polymath John Mitchell (1724-1793) in 1784. Later it was independently proposed by Pierre-Simon Laplace (1749-1827). Light was thought to consist of particles at this time. If the density of a celestial body became sufficiently large, and radius small enough, its escape velocity would become faster than the speed of light. Therefore, all light impinging upon it would be trapped.[2]

Black holes have a spherical boundary known as their *event horizon*. Should a mass find itself on the interior of this boundary, it cannot escape. Light generated inside of this boundary cannot propagate out, and is trapped within the event horizon. For an outside observer, the matter falling in slows as it approaches the event horizon, and never descends into the black hole. One of the most massive black holes observed to date is the supermassive central black hole of galaxy NGC 4889. Its event horizon is estimated at 62 Terameters—larger than our solar system.

The largest black hole currently identified is S5 0014+81 which is the engine of a powerful quasar. It is 113 Yottameters distant. It is so bright, that if it was moved to a distance of 2.65 Exameters from Earth, it would provide as much energy per square meter as the Sun does, despite being 18 megatimes further away. The diameter of black hole S5 0014+81 is thought to be 237 Terameters. This is over 40 times the radius of Pluto's orbit. Our solar system

shrinks to insignificance by comparison.

Terameter Separated Multiple Star Systems

Example	Type	Distance
Sirius AB	Binary	3 Tm
Alpha Centauri AB	Binary	4 Tm
Gamma Virginis	Binary	7 Tm
Eta Cassiopeiae (Achird)	Binary	11 Tm
Delta Cygni	Trinary	16 Tm
Mizar AB	Binary	57 Tm
Alpha Centauri C	Trinary	2200 Tm

Table 6.2

In other solar systems, Terameters can be useful when discussing distances between binary stars. The distance between two stars as they orbit their mutual barycenter can often be expressed in Terameters. Approximately half of the stars found in the Milky Way galaxy are thought to be binary or multiple star systems. Alpha Centauri is one example of a multiple star system. Alpha Centauri A and B form a binary star system, with a separation of about 1.65 Terameters at their closest approach. The two inner stars Alpha Centauri AB are circled by a third star, Alpha Centauri C, often called Proxima Centauri, at a distance of about 2200 Terameters. This separation distance is very large and although Proxima Centauri is believed to be gravitationally bound to Alpha Centauri AB, direct evidence of this is still to be discovered.

Two closely orbiting stars, with a third orbiting further out is a stable configuration, and quite common. Table 6.2 has a listing of the separations of some known binary and multiple star systems. The values are approximate since the distance between members of a multiple star systems varies.

Sirius, is a binary star system with Sirius A, a main sequence star which is the brightest in the night sky, and Sirius B, a white dwarf, orbiting their common center of gravity. The separation distance between them varies from 1.23 to 4.73 Terameters, and

so the semi-major axis length of 3 Terameters is listed. See Figure 6.1 Sirus is one of our nearest neighbors, only 81 Petameters from Earth. It is slowly moving toward our solar system. For the next 60 000 years it will increase in brightness, and then begin receding. It will become more faint after that, but will remain the brightest star in our night sky for around another 210 000 years. Under ideal conditions, Sirius is visible during the day.

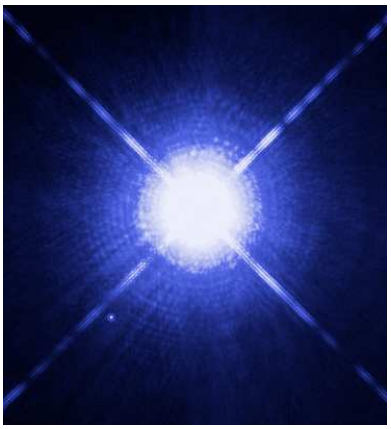

Figure 6.1: Hubble Space Telescope image of Sirius A and Sirius B. The white dwarf can be seen to the lower left. The diffraction spikes and concentric rings are instrumental effects. – Wikimedia Commons

Delta Cygni is a triple star system like Alpha Centauri. In approximately 11 500 years it will become the North Star, and remain so for about 400 years.

While Terameters *can* be useful for describing binary stars, there are many binaries with considerably smaller separations. For instance, Algol is a trinary star system consisting of Algol A, B, and C. Algol A and B orbit one another at a distance of only about 9.3 Gigameters (0.0093 Terameters). This orbital distance is six times closer than the orbital distance from Mercury to our Sun. Algol C orbits the pair at a distance of approximately 404 Gigameters (0.4 Terameters) or about the distance from the Sun to the asteroid belt between Mars and Jupiter. In other words, the Algol trinary star system would easily fit inside our Solar System with plenty of room to spare.*

These extremely close binary stars are generally so close, one

*One could make an argument that Gigameters would be a better unit for describing multiple star systems over their dynamic range of distance, which would make this a much shorter section.

cannot resolve them into separate stars optically, but the light spectra they emit, reveal the single point of light in our sky actually comes from two separate stars. Binaries which can only be resolved using their light signatures are called *spectroscopic binaries*. In Alpha Crucis for example, we find a binary pair of stars separated by 64 Terameters. The first of this binary pair (designated a^1) is itself a spectroscopic binary with a separation of only 150 Gigameters, or about the distance from the Sun to Earth.

It is hypothesized that long-period comets (those whose orbits take longer than 200 years) originate in the Oort cloud. The Oort Cloud is named for Dutch astronomer Jan Hendrik Oort (1900–1992). The Oort cloud is thought to be a roughly spherical cloud of icy objects, which extends from outside the Kuiper Belt, to halfway to our nearest stellar neighbor. The Kuiper Belt is thought to have a maximum extent of about 7.5 Terameters. The nearest star, Alpha-Centauri, is 41 305 Terameters from the Sun. So the Oort Cloud could extend from about 10 to 20 652 Terameters. The Oort cloud is the only astronomical candidate in our Solar System for an overall description using Terameters.

Linear Teraworld is a region that contains a contentious mystery. In January of 2016, Konstantin Batygin and Michael Brown of the California Institute of Technology announced indirect evidence for a new Planet X or Planet 9. Six previously cataloged trans-Neptunian celestial objects are clustered in a manner suggesting they are being ushered along by an unknown planet. This hypothesized planet is thought to be similar in composition and size to Neptune. Planet 9 would orbit the Sun about every 15 000 years. The closest approach of Planet 9 to the Sun is estimated at about 30 Terameters. Currently Voyager 1 is about 22 Terameters from the Sun. Planet 9 could have an apogee, or farthest distance from the Sun, of about 90 to 180 Terameters. If Planet 9 exists, then both Voyager Spacecrafts would still be inside our solar system.

Ironically, it was Michael Brown who discovered Eris in 2005. Eris is similar in size to Pluto, and its appearance marks the begin-

ning of Pluto's demotion from planet to dwarf-planet. Two years before locating Eris, Brown discovered Sedna, a small red colored object about 1000 Kilometers across. Sedna's orbital extent is from about 11 to 140 Terameters. Sedna also has the longest orbital period of any known minor planet at around 11 400 years. Peculiarities in the orbit of Sedna, and five other bodies, led Brown and Batygin to create a new Planet X, or Planet 9 hypothesis, after Brown had earlier helped to "kill planet Pluto," the original Planet X.

A very interesting project at Teraworld distance is the idea of creating a "Cosmic Telescope." [3] Light is bent around the perimeter of every star according to Einstein's theory of General Relativity. This ring shaped area acts as a "gravitational lens," bending the light toward a focal point about 80 Terameters from the Sun. An imaging device placed at this location has the potential to magnify an exoplanet, which is 950 Petameters away, by a factor of a million, (1 000 000). It would take a telescope with a 75 Megameter diameter (six times the diameter of the Earth), to equal the magnification of the Cosmic Telescope.

There are many engineering difficulties to overcome to create a Cosmic Telescope. First, it would be looking directly into the Sun. A coronagraph or starshade would be needed to block the light from the Sun, and allow only the light from the gravitational lens to pass through. The starlight from the parent star of the exoplanet would be 10 mega-times weaker (10 000 000), than that seen through a conventional telescope. This bright light confounds current imaging attempts.

The Cosmic Telescope image will look like a ring of light (Einstein ring), which corresponds to a tiny area of the exoplanet's surface. The imaging of the planet would be done pixel by pixel, with considerable imaging analysis required. The Cosmic Telescope spacecraft would be moved in a spiral fashion to slowly image the exoplanet as each Einstein ring of each pixel is taken. A Cosmic Telescope has the potential to produce high resolution images of exoplanets, possibly revealing oceans and mountain ranges,

which orbit stars up to 950 Petameters distant.

The largest known Red Supergiant star is Stephenson 2-18, which is about 189 Exameters distant. It has radius of 1.5 Terameters. This is 2150 times the radius of our Sun. If Stephenson 20-18 was a meter across, our Sun would be about one-half millimeter in diameter. This means that if it were substituted for our Sun, it would extend to the orbit of Saturn. The circumference of Stephenson 2-18 is about 9.4 Tm. Traveling at the speed of light, it would take close to 9 hours to travel along its equator.

6.2 Teraworld Area

1 – 1 000 000 Square Terameters (Tm^2) 1 x 10^{24}

List of Terameter Areas

Example	Area
Area Swept by Jupiter's Orbit	1.9 Tm^2
Surface Area of Antares	4.7 Tm^2
Area Swept by Saturn's Orbit	6.4 Tm^2
Surface Area of Betelgeuse	7.0 Tm^2
Surface Area of NML Cygni	16.6 Tm^2
Surface Area of VY Canis Majoris	24 Tm^2
Area Swept by Uranus' Orbit	26 Tm^2
Area Swept by Neptune's Orbit	64 Tm^2
Area Swept by Pluto's Orbit	110 Tm^2

Table 6.3

Teraworld area is the domain of giant red stars. When a star has exhausted its supply of hydrogen through nuclear fusion, and if it has a mass about ten times our Sun's, then it will begin to fuse helium, and become a red giant star.

The red supergiant star Antares has a diameter 883 times that of our Sun, or 1.23 Terameters. Its surface area is 4.73 square Terameters. Betelgeuse is a red giant star in the Orion constellation. The star is distinctly reddish, and its color may be seen

without the aid of a telescope. Betelgeuse has a surface area of approximately 7 square Terameters. The Red hypergiant star NML Cygni has a diameter about 1650 times that of the Sun, or 2.3 Terameters. Its surface area is about 16.6 square Terameters. We have reached the limits of the surface area of celestial objects, and only a sphere enclosing spherical groups of stars will have a surface area larger than square Terameters.

6.3 Teraworld Volume

1 – 1 000 000 000 Cubic Terameters (Tm^3) 1 x 10^{36} m^3

1 – 1000 Teraliters (TL) 1 x 10^{12} L

Teraliters are useful for expressing the amount of water behind human created dams. Hoover Dam causes the Colorado River to pool into Lake Mead, which contains 37 Teraliters of water. The Aswan High Dam spans the river Nile to broaden out into the 157 Teraliters of water we call Lake Nasser. The largest body of water behind any dam on Earth is Lake Kariba in Zimbabwe, at an astounding 180 Teraliters.

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List of Teraliter Volumes

Example	Volume
Salton Sea	7 TL
Lake Mead (Hoover Dam)	37 TL
Lake Nasser (Aswan High Dam)	157 TL
Mount Tambora (volcano) Ejection Volume	160 TL
Lake Kariba (Kariba Dam)	180 TL
Volume of Crude Oil on Earth	300 TL
Lake Erie	480 TL
Lake Ontario	1 640 TL
Lake Huron	3 543 TL
Lake Michigan	4 918 TL
Lake Superior	12 088 TL

Table 6.4

In 1900, an irrigation canal was dug to provide water from the Colorado River to the Imperial Valley. The canal was a success, but began to fill with silt. The banks of the Colorado River were widened, and cuts made to increase the flow of water to the farm land. A spring flood produced so much water in 1905 that it breached a head-gate, which drained into the Salton Basin. Water flowed into this ancient lake bed for over two years before repairs halted it. This water formed a lake about 24 x 54 Kilometers in extent.

This new lake became known as the Salton Sea. The Salton Sea would likely have dried up, but because of the considerable amount of water provided to farmers, the excess flowed into the lake. Restaurants, hotels, vacation homes, yacht clubs, and event centers, such as Bombay Beach, appeared along its shore. From the 1950s into the 1960s, the Salton Sea became a popular resort. Tourists fished, water skied, and watched headline entertainers like Frank Sinatra and The Beach Boys. At the peak of the Salton Sea's popularity, over 1.5 million people visited each year

In the 1970s, warnings were issued that because the Salton Sea had no outlet, and was only replenished from runoff, it would soon begin to concentrate salts, selenium, and fertilizers. By the end of the decade, fish, birds, and other wildlife began dying off. During that decade, a number of tropical storms quickly increased the water level of the Salton Sea, which flooded the surrounding buildings. In particular, Hurricane Kathleen engulfed the shoreline communities in 1976. Bombay Beach was completely underwater. Tourism rapidly declined; the infrastructure and many resorts were abandoned. Much of what is left looks like a post-apocalyptic landscape.

The lake began to reek. The smell could be overwhelming. By the 1990s, fish die-offs produced shorelines that were littered with dead fish. Often when storms would agitate the waters, botulism from algae blooms would kill the tilapia, which birds would ingest, killing tens of thousands of them. There have been many discussions about possible ways to reclaim the Salton Sea over the years,

but none has been funded or implemented. Currently the Salton Sea contains about 7 Teraliters of water.

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On April 10, 1815, Mount Tambora in Indonesia produced the largest volcanic eruption in recorded history. The volcano expelled 160 Teraliters of material into the atmosphere. The sound of the explosion was heard as far away as Sumatra, which is 2000 Km distant (the length of Montana is about 1000 Km). At least 71 000 people perished. The large amount of matter introduced into the Earth's atmosphere produced a "volcanic winter." 1816 became known as "The Year Without a Summer." Crops and livestock all over the Northern Hemisphere perished, producing the worst famine of the nineteenth century.

The Sun's now red-hued light was so attenuated and altered by the "dry fog" of the Tambora ash clouds, that on the East Coast of the United States, sun spots were visible to the unaided eye. In the Northeastern United States, freezing weather was recorded in May, June, July, and August.

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The largest fresh water lakes in the world are the five Great Lakes in the US and Canada. The smallest of these, Lake Erie and Lake Ontario, each have more volume than the estimated total volume of crude oil which originally existed on Earth (300 TL). Lake Erie has 480 Teraliters of fresh water, and Lake Ontario squeezes past the Teraliter boundary with 1640 Teraliters.

$\mathrm{Tm}^3 \bullet\bullet\bullet \mathrm{Tm}^3$

List of Cubic Terameter Volumes

Example	Volume
Betelgeuse	2.5 Tm^3
Sphere Enclosing Neptune's Orbit	382 Tm^3
Sphere Enclosing Voyager I	34 066 Tm^3

Table 6.5

Betelgeuse, a red supergiant star in the constellation of Orion, has a diameter of 1.671 Terameters, with an enclosed volume of about 2.46 Tm^3.

The extent of Neptune's orbit is about 9 Terameters. A sphere with this diameter encloses all the planets in the Solar System and encompasses a volume of 382 cubic Terameters.

The Voyager 1 spacecraft is currently 20 Terameters from Earth. An enclosing sphere of this radius would contain a volume of 34 066 Tm^3

6.4 Teraworld Mass

1 – 1000 Teragrams (Tg) 1 x 10^{12} g

Items with Teragram Mass

Example	Mass
Mass Converted to Energy in the Sun Each Second	4.3 Tg
The Great Pyramid at Giza	5.9 Tg
Rocky Mountain Locust Swarm (1877)	28 Tg
Sand & Gravel Extracted Worldwide Each Year	50 Tg
Amount of Concrete in Three Gorges Dam	60 Tg
Ice Lost by The Greenland Ice Sheet Per Year (2019)	267 Tg
Mass Ejected from Meteor Crater	318 Tg
Total Mass of Humans (2006)	423 Tg

Table 6.6

Our Sun produces its energy by fusing four hydrogen atoms into a single helium atom. After this transformation of elements takes place, some mass is left over which is then released as energy in an amount predicted by Einstein's famous equation $E=mc^2$. The Sun creates 385 Yottajoules of energy each second. The amount of mass transformed by energy conversion, is 4.26 Teragrams every second. This seems like a considerable amount of mass, but when compared with the Sun's colossal mass of about 2 000 000 000 Yg, the ratio of mass lost per second to the mass of the Sun is 0.000 000 000 000 000 000 002 which is infinitesimal. It takes about 45 000 000 years, for a mass equivalent to that of the Earth to be converted to energy with this process. The Earth's mass is a piddly 6000 Yottagrams, and its loss is still of little consequence to the mass of the Sun.

The Great Pyramid at Giza is estimated to possess a mass of 5.9 Teragrams. This much mass is transformed into energy inside the Sun every 1.4 seconds.

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The amount of sand and gravel mined each year worldwide

has a mass of approximately 50 Teragrams. While sand appears ubiquitous, the sand which is useful for producing concrete is not. Sand in deserts such as those found in the Sahara, have been formed by wind action, which produces grains which are round in shape, and impractical for use in construction. Round grains do not interlock. Jagged edged sand grains are required to produce structurally strong concrete. Desert sands are essentially useless; which is why Saudi Arabia imports sand for construction use.

Sand which has been produced in the beds, banks, and flood planes of rivers is rather sharp-edged, as is the sand found in lakes and along seashores. The demand for angular sand has depleted this resource, and world wide shortages are occurring, as the population of the Earth increases without restriction.

Figure 6.2: Three Gorges damn in Hubei Province China – Wikimedia Commons

The Three Gorges Dam in China, which spans the Yangtze River, is the world's largest concrete structure. It took 17 years to construct. The dam contains 60 Teragrams of concrete for a mass that is about ten times the mass of the Great Pyramid at Giza. The next largest concrete structure is the Grand Coulee Damn in Washington State, which has 22 Teragrams. This is followed by the Panama Canal with about 7 Teragrams, and the Hoover Dam with 6 Tg.[4] The Three Gorges dam utilized about 464 Gigagrams of steel for its construction. It has a length of 2.335 Km.

The Three Gorges Dam flooded an area of 632 Km^2, containing a volume of water of about 39 Km^3. The reservoir it formed is

about 600 Km in length, which displaced about 1 000 000 people. The water itself has a mass of about 39 Petagrams, and as the reservoir filled, increasing the height of the water, it changed the moment of inertia of the planet, and altered the rotation of the Earth. The change in rotation is small. The length of our day was increased by a miniscule 60 μs. The 2011 mega earthquake in Japan is said to have altered the Earth's rotation by about 2680 μs.

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Ice which is on land, then melts and flows into the ocean, is a direct contributor to sea level rise. Because of Global Warming, the ice on The Greenland Ice Sheet is losing nearly 267 Teragrams of ice each year. This melting by itself raises sea level by about 0.7 mm per year. The Greenland ice is melting about 7 times faster than it was in the 1990s.[5]

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It is estimated between 272 and 363 Teragrams of rock were displaced to create Meteor Crater in Arizona.

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The total mass of humans on Earth is estimated to be about 423 Teragrams. In 100 seconds, the mass lost to fusion within the Sun is slightly more than the mass of all the human beings on the Earth.

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