Modeling Gravity on the Inner Surface of a Dyson Sphere

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1 Abstract

A Dyson sphere was first written by olaf Stapledon in the early 1900s and made popular by its namesake: Freeman Dyson later in the century. The application of a sphere with our technology would be impossible, but hypothetically speaking if we wanted to create a Dyson sphere around our sun and maintain a gravity of an Earth-like environment on the interior, a biosphere, we would need to rotate the sphere. The angular velocity required would be roughly 8.1003e-6 rad/s. Although the biosphere would not be able to encompass the entire interior wall of the Dyson and because of the interaction between centrifugal and gravitational force the biosphere would be condensed to the area around the equator of the Dyson sphere. This would result in a Niven ring.

2 Introduction

The concept of a Dyson sphere was first described by Olaf Stapledon in his science fiction novel Star Maker. The purpose of a Dyson sphere is to harness the entire energy output of a star as usable energy. The namesake of the design comes from Freeman Dyson who wrote Search for Artificial Stellar Sources of Infrared Radiation. Dyson discussed that a civilization that had the capacity to build such a construction would ultimately require the amount of energy that was to be harnessed as a necessity; a logical consequence of long-term survival for an expanding civilization.

A Dyson sphere is defined as a uniform solid shell of matter encompassing a star. A sphere with radius of one astronomical unit around our sun would receive all 384.6 yottawatts (3.846e26 watts). Because of shell theorem the sphere would have no net gravitational forces from the sun and therefore could drift around a stationary star. If the sun had velocity the Dyson sphere would need have a method of propulsion to avoid any collision.

Another application that a Dyson sphere could be used for is to create a biosphere, or livable environment on the interior service of the Dyson sphere. The purpose of the biosphere being on the interior is another concept of shell theorem and therefore the contents of the biosphere would not experience a gravitational pull from the sphere and would fall into the sun. In order to counteract this falling the Dyson sphere, which the biosphere would be built off of, would need to utilize the principles of rotational kinematics.

If the sphere was to rotate the contents on the biosphere would feel forces perpendicular to the axis of rotation pushing them away from the star and because of Newtons laws of motion a feeling of gravity would result, therefore creating a simulated or artificial gravity.

3 Methods

In order to simulate a Dyson sphere around the sun, our goal was to model the conditions to allow for a biosphere to exist on the interior. The main concern for these conditions was to figure out the gravity felt by the contents of the biosphere. First step was to establish the correct angular velocity for the sphere needed to compensate for the gravitational pull the sun would have. From here a mesh grid for phi and theta and i, j, and k vector fields were built. Next step was to calculate the force of gravity the sun would cause. The gravitational force equation was used and dotted into each i, j, and k vectors.

Insert gravitational force equation

$$F = ((G * m1 * m2)/r^3) * < i, j, k > \tag{1}$$

Gravity from the Dyson sphere on the biosphere is unnecessary due to shell theorem and therefore was excluded from the code. The centripetal force was calculated using:

Insert centripetal force equation

$$a = w^2 * sin(phi) * < i, j, k > \tag{2}$$

and lastly the net force was calculated with,

net force equation

$$Fnet = F1 + F2 + ... + Fn \tag{3}$$

A vector field plot was then constructed to visualize the force of gravity for the system.

4 Results

The gravity for Earth-like conditions was constructed by establishing an angular velocity of 8.1003e-6 rad/s. The Earth-like gravity was established around the equator of the sphere. For a sphere uniform artificial gravity cannot exist and as a mass moves along the inside of the sphere, the farther from the axis of rotation, the stronger the feeling of gravity will be. The centripetal force of gravity combined with the gravitational force of gravity results in the gravity for the system along the sphere to point toward the equator as well. Therefore, for an ideal biosphere, conditions around the equator are the most important. The calculated force of constructed gravity was approximately 9.81 N per 1 kg in my simulation at the equator. The result of Earth-like gravity and a vector field pointing toward the equator would result in a Niven ring as time increases to infinity. Essentially the biosphere would condense to a ring around the equator.

See appendix for a model of the sphere with the vector field for net force along the Dyson sphere.

5 Conclusion

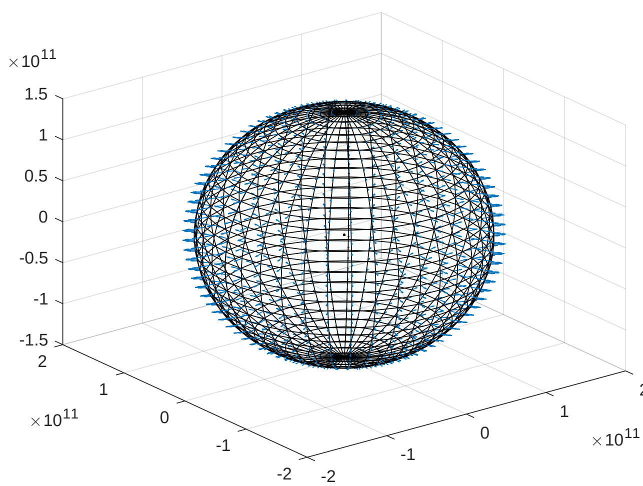
The point of a Dyson sphere is to entirely encapsulate a star in order to completely harness the energy output of it. The application of it with our technology would be impossible, but hypothetically speaking if we wanted to create a Dyson sphere around our sun and maintain a gravity of an Earth-like environment on the interior, a biosphere, we would need to rotate the sphere. The angular velocity required would be roughly 8.1003e-6 rad/s. Although the biosphere would not be able to encompass the entire interior wall of the Dyson and because of the interaction between centrifugal and gravitational force the biosphere would be condensed to the area around the equator of the Dyson sphere. This would result in a Niven ring.

6 Appendix

```
prompt = 'Insert number of steps : ';
numSteps = input(prompt);
numSteps = numSteps - 1;
timeStep = 1;

%1 AU = 1.496e+11 m
r = 1.496e11; %radius of Dyson sphere
```

```
rSun = 696.3e6; %radius of sun/star
%calculating velocity of sphere to model Earth-like gravity at equator o
    %sphere
f = 9.81 + .0059; % force desired at equator outset to account for sun's
m = 1;
a = f / 1;
w = sqrt(a / r);

%let theta be from 0 to 2pi
thetaStep = 2 * pi / numSteps;
theta = meshgrid(0:thetaStep:2 * pi);
%let phi be from 0 to pi
phiStep = pi / numSteps;
phi = meshgrid(0:phiStep:pi);

%To create a dyson sphere
[i,j,k] = sphere(numSteps);
i = i .* r;
j = j .* r;
k = k .* r;
surf(i,j,k)
alpha 0.01
hold on
%to create the sun
[x,y,z] = sphere(numSteps);
x = x .* rSun;
y = y .* rSun;
z = z .* rSun;
surf(x,y,z)

%gravitational force of sun for a person
G = 6.67408e-11;
mSun = 1.989e30; %mass of our sun
mTest = 1; %mass of test subject on biosphere
fiSun = -1 * ((G * mSun * mTest) / r^3) .* i; %force of gravity due to s
fjSun = -1 * ((G * mSun * mTest) / r^3) .* j; %force of gravity due to s
fkSun = -1 * ((G * mSun * mTest) / r^3) .* k; %force of gravity due to s
```

```
aCent = w^2 .* sqrt(i.^2 + j.^2);
%z dotted with aCent
iCent = aCent .* cos(theta);
fiCent = iCent .* mTest;
%y dotted with aCent
jCent = aCent .* sin(theta);
fjCent = jCent .* mTest;
%z dottted with aCent is 0 because since the rotation is along
    %the z axis, there is no z acceleration
kCent = w^2 .* k .* 0;
fkCent = kCent .* mTest;

%Calculating net aforce m_test experiences on biosphere
fiNet = fiSun - fiCent;
fjNet = fjSun - fjCent;
fkNet = fkSun - fkCent;

%quiver of net force from "gravity" an object feels at position x along
    %curve of the sphere
quiver3(i,j,k,fiNet,fjNet,fkNet)

%quiver3(x,y,z,fxSun,fySun,fzSun)
%quiver3(i,j,k,fiCent,fjCent,fkCent)
hold off
```


×10^11
1.5
1
0.5
0
-0.5
-1
-1.5
2
1
×10^11
0
-1
-2
-2
-1
0
1
2
×10^11

References

[1] Freeman J. Dyson *Search for Artificial Stellar Sources of Infra-Red Radiation* (1960). Science 131: 1667-1668.

[2] *Dyson Sphere* (2016). Wikimedia.