Stellar System Creator

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CHAPTER ONE

INTRODUCTION

The Solar System Creator is a python package that aims to ease the creation of realistic stellar systems in sci-fi settings. With minimal input, the user is able to create stars, planets, moons, asteroid regions and other celestial bodies, with accurate physical characteristics, declare their habitability, extract physical characteristics and visualize them.

CHAPTER

TWO

QUANTITIES

Here, we will explore the various physical quantities found in this package.

2.1 Material

2.1.1 Mass

Mass is the quantity of mater in a physical body. In the context of this package, mass determines most of other physical characteristics, like *radius*, *luminosity*, *spin period* and *lifetime*.

Suggested (approximate) masses:

1. For mon-like satellites, less than 0.05 earth masses (Me)
2. For rocky planets: up to around 5 earth masses
3. For ice-giants: between 5 and 100 earth masses
4. For gas-giants: between 100 earth masses and 10 jupiter masses (Mj)
5. For long-lived, red stars: 0.081 and 0.5 solar masses (Ms)
6. For habitable stars: 0.6 to 1.4 solar masses
7. For short-live, big blue stars: 1.4 to 50 solar masses.

2.1.2 Density

Density ($\rho = \frac{M}{V}$) is the *mass* per unit *volume* of an a substance (or celestial object). Usual densities in the solar system are between 0.5 and 7 grams/cm^3.

2.1.3 Composition Type

The composition type of planets, planetoids, asteroids etc. is what the approximate composition of a celestial object will be. There are two types of iron worlds, two types of rocky worlds, four types of water worlds, one type of ice- and one of gas-giants.

Even though the composition is not accurate by itself, I find that the *density* and *radius* of asteroids and moons that are not rocky, can be generally approximated by the four different water worlds. Same for small gassy worlds (like Pluto).

2.1.4 Chemical Composition

Chemical composition is the ratio of different chemical compounds that constitute a substance. There are 3 main substances that are portraited in this package. That does not mean that there can not be other, it is just what the planetary *radius* models represent.

The main chemical compounds are iron (Fe), rock ($MgSiO_3$), water (H_2O), helium (He), Hydrogen (H_2) and methane (CH_4).

2.2 Geometric

2.2.1 Radius

Radius is the variable that defines the size of celestial objects. The radius determines the *circumference*, *surface area*, *volume* and *density*. among other characteristics. The suggested radius is determined by the *mass* of the object via various radius models. Use values ± 8 % around the suggested value.

Models used:

1. For planetary models, see https://arxiv.org/pdf/0707.2895.pdf.
2. For hot gas-giant models, see https://arxiv.org/pdf/1804.03075.pdf.
3. For star models, see https://academic.oup.com/mnras/article/479/4/5491/5056185.

2.2.2 Circumference

The circumference is determined by the radius $C = 2\pi r$.

2.2.3 Surface Area

The surface area is determined by the radius $A = 4\pi r^2$.

2.2.4 Volume

The volume is determined by the radius $V = \frac{4\pi}{3} r^3$.

2.3 Rotational

2.3.1 Spin Period

The spin period is the amount of time it takes for a celestial body to rotate around itself compared to the distant stars.

Planetary spin period is determined by the *mass* and *radius* of the celestial body. The more massive the body, the faster it rotates. If there are satellites around the planet large enough (e.g. earth-moon), there is a substantial transfer of angular momentum between the two bodies, making the planet slow down (earth spin period would have been around 16 hr).

2.3.2 Day Period

The day period of a child body is determined by the *spin period* and the *orbital period* around the parent body.

2.3.3 Axial Tilt

The axial tilt of a child body, also known as obliquity, is the angle between an object's rotational axis and its orbital axis.

As of now, it is cosmetic and does not determine any other characteristics.

2.4 Life

2.4.1 Age

The suggested age of a star is set to be half of its *lifetime*. The suggested age of any other object is determined by it's parent age.

2.4.2 Lifetime

The lifetime of stars is determined by its mass and its luminosity ($T = \frac{M}{L}$).

The lifetime of each other body is determined by the lifetime of the parent minus a hundred million years, which is roughly the amount of time it takes for planets to form around stars (or satellites to be captured). It is by no means binding.

2.5 Surface

2.5.1 Emission

Albedo

Emissivity

Heat Distribution

Normalized Greenhouse

Incident Flux

Temperature

Luminosity

Peak Wavelength

2.5.2 Gravity

Surface Gravity

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2.5.3 Internal Heating

Tectonic Activity

Primordial Heating

Radiogenic Heating

Tidal Heating

2.5.4 Induced Tide

2.5.5 Angular Diameter

2.6 Orbital

2.6.1 Eccentricity

Eccentricity e determines how elliptic the orbit of a child around a parent body is. $e = 0$ means that the orbit is circular, and $e = 1$ means that the orbit resembles a line (not a stable orbit).

2.6.2 Semi-Major Axis

Semi-major axis a is the mean distance between a child and a parent body.

2.6.3 Semi-Minor Axis

Semi-minor axis b is determined by the *semi-major axis* a and the *eccentricity* e: $b = a\sqrt{1 - e^2}$.

2.6.4 Apoapsis

Apoapsis ($a(1 + e)$) is the furthest distance between a child and a parent body. It is determined by the *semi-major axis* a and the *eccentricity* e.

2.6.5 Periapsis

Periapsis ($a(1 - e)$) is the nearest distance between a child and a parent body. It is determined by the *semi-major axis* a and the *eccentricity* e.

2.6.6 Lagrange Position

Lagrange positions (L#) are (semi-)stable positions between two orbiting objects. Trojans are objects in the L4 and L5 positions, in front and behind the child object (denoted as +1 and -1 respectively) that is orbiting a parent object.

2.6.7 Contact

In this context, contact between two binary stars happens if the radius of at least one of the two stars resides outside the roche lobe while the stars are in *periapsis*.

2.6.8 Roche Lobe

The Roche lobe is the region around a star in a binary system within which orbiting material is gravitationally bound to that star.

2.6.9 Orbital Period

Orbital period ($\sqrt{\frac{a^3}{M_{tot}}}$) is the time it takes for a child body to orbit around their parent. It is given by the *semi-major axis* a, and the total mass M_{tot} of child and parent objects.

2.6.10 Orbital Velocity

Orbital velocity ($\sqrt{\frac{M_{tot}}{a}}$) is the mean speed at which the child body travels around the parent body. It is given by the *semi-major axis* a, and the total mass M_{tot} of child and parent objects.

2.6.11 Orbit Type

Orbital type of a child object can be either prograde or retrograde - orbiting along or against the rotation of the parent.

2.6.12 Orbit Type Factor

Orbit type factor determines the *semi-major axis maximum limit*. It depends on the *orbit type* and is determined by the parent *eccentricity* e_p and the child *eccentricity* e_c.

1. For a prograde orbit, it is given by $0.4895(1 - 1.0305e_p - 0.2738e_c)$.
2. For a retrograde orbit, it is given by $0.9309(1 - 1.0764e_p - 0.9812e_c)$.

2.6.13 Orbital Stability

Orbital stability demonstrates if the orbit of the child object around the parent object does not exceed any limits. More specifically, for a stable orbit we must have:

1. *Periapsis* > *roche limit*.
2. *Semi-major axis* > *p-type critical orbit*.
3. *Apoapsis* < *semi-major axis maximum limit*.
4. Optional: *Semi-major axis* > *parent inner orbit limit*.

5. For rock worlds: *Semi-major axis* > *parent outer rock formation limit*.

2.6.14 Inclination

Orbital inclination is the tilt of a child object's orbit around a celestial body. It varies between 0 and 180. Between 0 and 90, the orbit is prograde. Between 90 and 180, the orbit is retrograde.

However, as of now, it is cosmetic and does not determine any other characteristics, including the *orbit type*.

2.6.15 Argument of Periapsis

Check out https://en.wikipedia.org/wiki/Argument_of_periapsis.

The argument of periapsis, as of now, it is cosmetic and does not determine any other characteristics.

2.6.16 Longitude of the Ascending Node

Check out https://en.wikipedia.org/wiki/Longitude_of_the_ascending_node.

The longitude of the ascending node, as of now, it is cosmetic and does not determine any other characteristics.

2.6.17 Semi-Major Axis Minimum Limit

The semi-major axis minimum limit is the *roche limit* of the parent for the specific child *density*, or the *p-type critical limit* in binary systems.

2.6.18 Semi-Major Axis Maximum Limit

The semi-major axis maximum limit is the *hill_sphere* multiplied by the *orbit type factor*.

2.7 Children Orbit Limits

2.7.1 Tidal Locking Radius

2.7.2 Roche Limit

2.7.3 Dense Roche Limit

2.7.4 P-type binary Critical Orbit

2.7.5 Inner Orbit Limit

2.7.6 Hill Sphere

hill sphere or roche lobe

2.7.7 S-type binary Critical Orbit

2.7.8 Outer Orbit Limit

2.7.9 Inner Rock Formation Limit

2.7.10 Outer Rock Formation Limit

2.7.11 Inner Water Frost Limit

2.7.12 Sol-Equivalent Water Frost Limit

2.7.13 Outer Water Frost Limit

2.8 Insolation Models

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2.9 Habitability

CHAPTER THREE

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