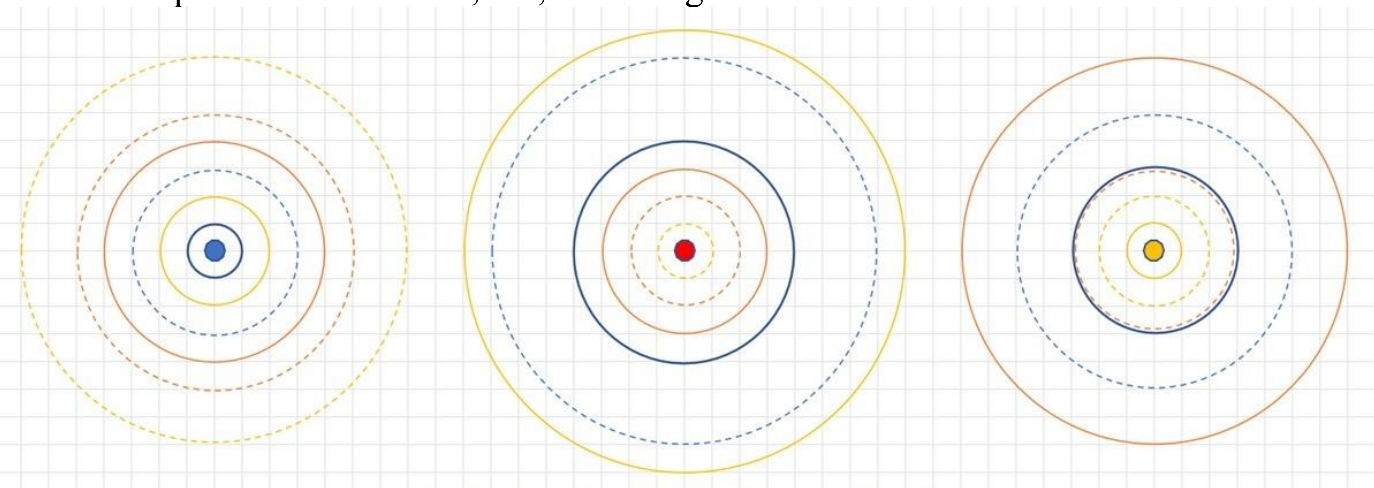
<u>Artificial Universes</u>
– <u>to do list</u> –

1) **Colored forces (Interactions)** which can take two forms:
   a. Attraction or Rejection per interaction is determined by:
      - A matrix of intensities of attractive or repulsive forces, having values in the range (-i, i), where the negative number represents attraction, and the positive number represents repulsion.
      - A matrix of radii of action of attractive or repulsive forces having values in the range (0, r).

   b. Attraction and Rejection per interaction is determined by:
      - A matrix of attractive force strengths, which has values in the range ($-f_a$, 0).
      - A matrix of repulsive force strengths, which has values in the range (0, f_r).
      - A matrix of the radii of action of the attractive forces, which has values in the range (0, r_a).
      - A matrix of the radii of action of repulsive forces, which has values in the range (0, r_r).

   These interactions and phenomena are explained in the following example:
   Let 3 particle colors: blue, red, and orange.



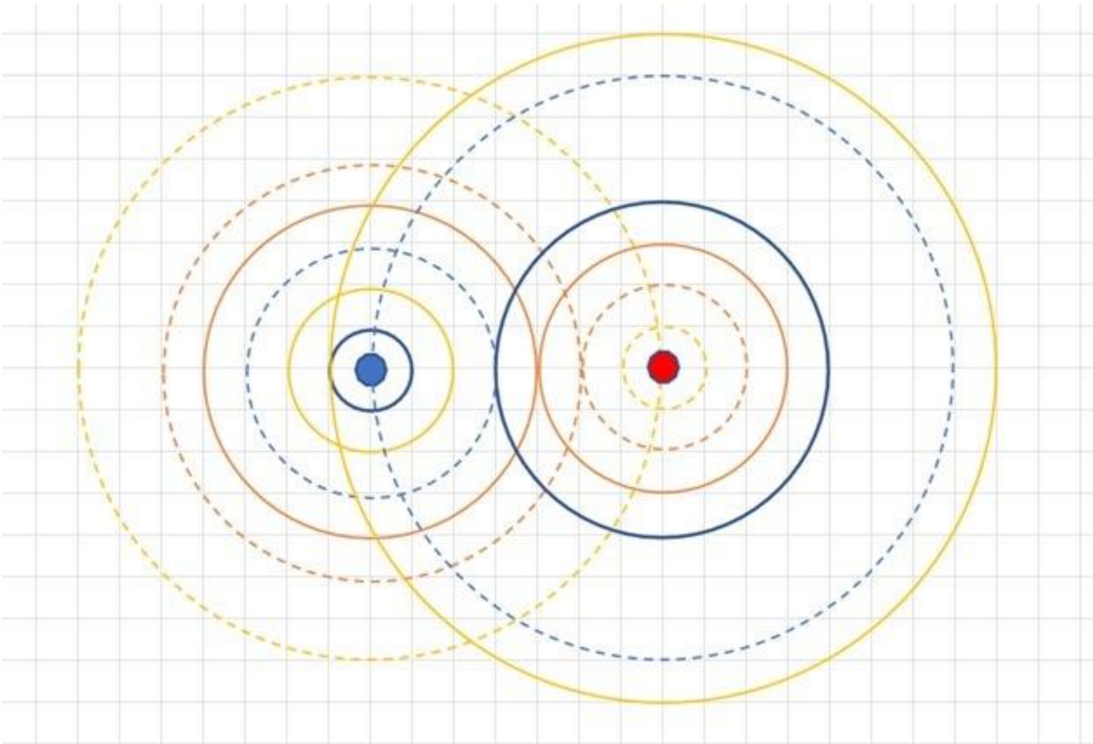
I+	B	R	O
B	4	7	3
R	5	2	6
O	1	8	9

R+	B	R	O
B	1	4	2
R	4	3	8
O	3	7	1

I-	B	R	O
B	6	2	9
R	1	7	5
O	4	8	3

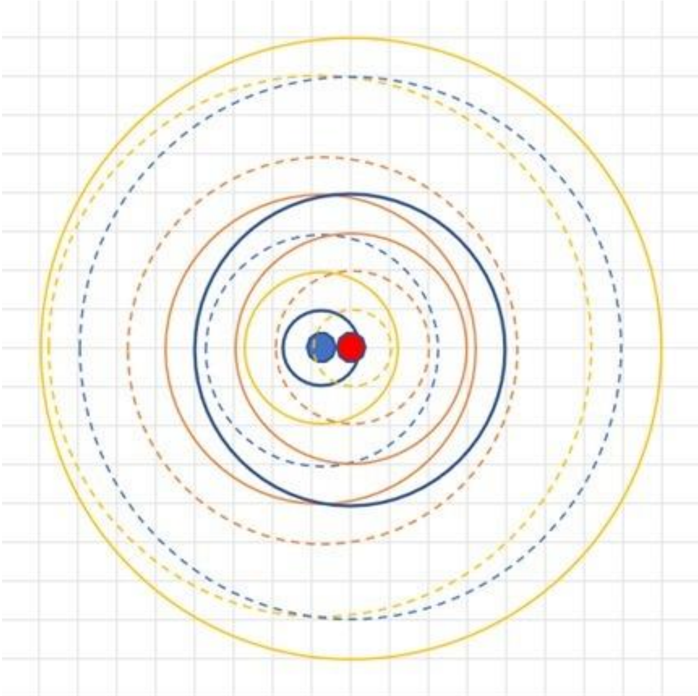
R-	B	R	O
B	3	5	7
R	7	2	1
O	5	3	2

We have the 4 matrices of colored interactions: of the intensity of the attractive force (I+), of the radius of action of the attractive force (R+), of the intensity of the repulsive force (I-), of the radius of action of the repulsive force (R-). Each colored particle emits a colored force field around itself over a distance corresponding to the radius of action of each type of force.
Suppose the blue particle is coming towards the red particle, being pushed by the orange particle.

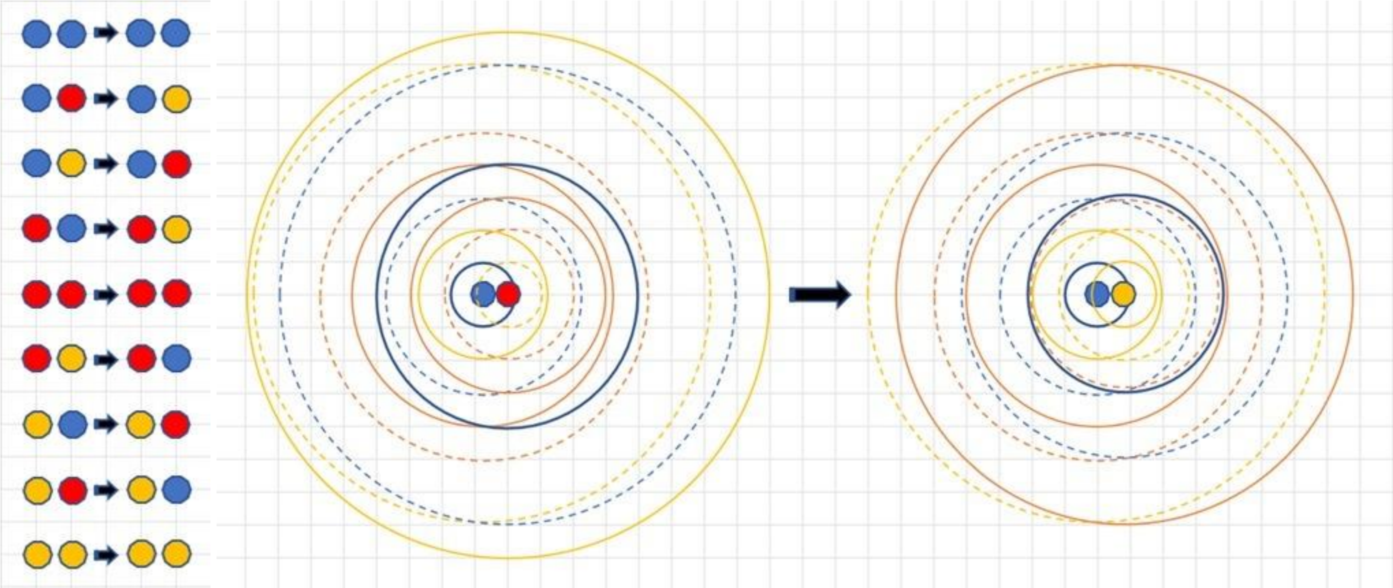


The two stops in this position, i.e., at a distance of 7 from each other. Why? Because red repels blue up to a distance of 7, and the attraction between the two is less than 7 (4 and 4). Blue attracts red, but only up to a distance of 4 and with an intensity of 7, but it cannot approach red because red repels it and keeps it at a distance of 7 from it.

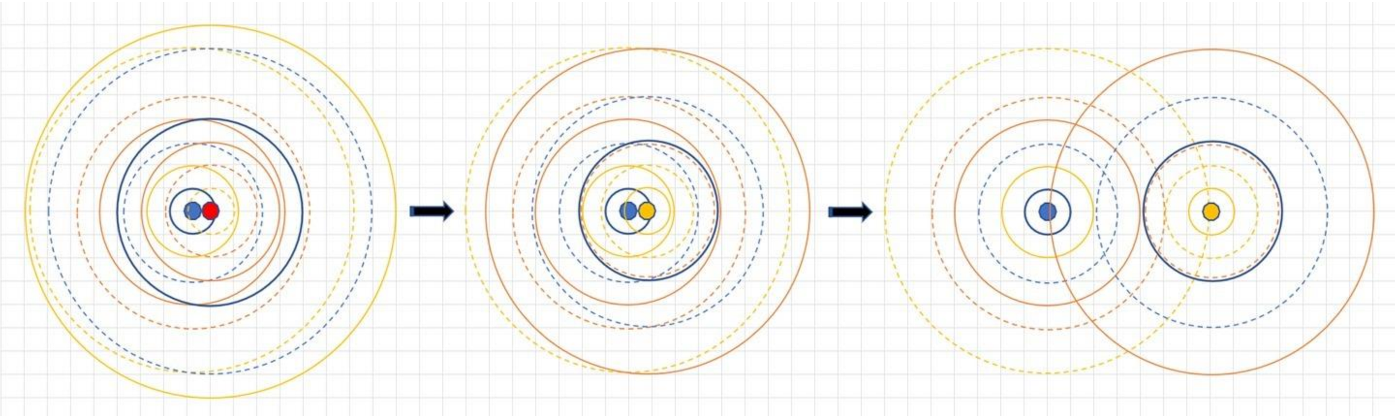
All linear kinetic energy (of motion) is converted into circular kinetic energy, i.e., blue will rotate around red until a certain time T. Why? Because each particle emits force fields in a spiral, inward to outward for repulsive forces and outward to inward for attractive forces. How long does this T last? Well, that depends on the viscosity (frictional force). If we have a viscosity of 50%, then the blue will lose 50% of its circular kinetic energy at each time step. If blue had an initial kinetic energy of 100 at time step T_0, then at T_1 it will have 50, at T_2 it will have 25, at T_3 it will have 12.5, at T_4 it will have 6.25 and so on until the kinetic energy equals the minimum allowable energy of the system. If the system has a defined minimum kinetic energy of 1, then at time step T_7 the blue will stop. If the minimum kinetic energy is set to 0, then blue will never stop, but will slow down to infinity. If the blue particle is pushed (hit) by another particle and gets closer to the red particle (at a distance of 4), then the red will attract the blue and the blue will attract the red with a force calculated as follows: BR(+) + RB(+) - BR(-) - RB(-) = 7 + 5 - 2 - 1 = 12 - 3 = 9. Therefore, the bond between blue and red at zero distance is 9. This bond can only be broken if this group is hit by a force greater than 9.



2) **Probability of interaction**: each interaction in (1) has a certain probability determined by a probability matrix, which has values in the range (0.00, 1.00).
3) **Interaction viscosity**: each interaction in (1) has a certain viscosity determined by a viscosity matrix, which has values in the range (-1.00, 1.00). Note: negative viscosity increases particle velocity at each time step, and positive viscosity decreases it at each time step. The value -1.00 means double velocity per time step and 1.00 means zero velocity per time step.
4) **Circular motion**: When the attractive forces cancel with the repulsive forces, and the force resulting from their combination is of zero intensity, then all the kinetic energy of the particles is converted into circular motion along the curved line where the forces cancel. The motion is not necessarily in the shape of a circle, but follows the neutralization curve, which can be circle, oval, or some other shape, but is always closed. This leads to the formation of a bond between particles and the creation of a meta-particle, whose edge is the line described by the edge of the particles moving on the neutralization curve. The particles remain bound until an external force (another particle or group of particles) intervenes to hit or influence them and remove them from the bound. With this property one can create groups of particles that form stable structures with stable bonds, necessary for another application option, i.e., the metaparticle.
5) **Reactivity**: Particles can change color when they touch. At each touch the colors of the particles change according to a matrix called the reactivity matrix. For example, if a particle of color X touches a particle of color Y, then X can turn into a Z and Y into a Q, and X will behave as a Z and Y as a Q.
   When the two particles touch, they are likely to react to this touch and recolor. This means that when blue touches red, it changes color to orange, and this is shown by the reactivity table.



By changing its color, the force fields also change and so do the interactions between the two particles. Because if red turns orange, the force fields of red are replaced by those of orange. So, the encounter between the blue particle and the red particle happens like this:



So, particles approach, then touch, then react and transform, then change their fields and interactions with each other, and then move away according to the new fields given by the interaction force matrices and radii. All this takes place in a probability field given by user-defined probability parameters.

6) **Probability of reactivities**: each reaction in (4) has a certain probability of happening, determined by a matrix of reaction probabilities, which has values in the range (0.00, 1.00).

7) **Gravitational forces**: each particle can have mass that will take values in the range ($-m_n$, $+m_p$). This mass will cause a gravitational or antigravitational force of infinite range, whose intensity decreases with the square of the distance, according to the formula of gravitational attraction in relativistic system. We have two components:
   a. The initial mass, m_0, which is given by the user.
   b. Relativistic mass, m_r, is given by the kinetic energy of the particle.
   c. Total mass, mt, which is the sum of the above two masses: $m_t = m_0 + m_r$.
   d. The gravitational constant, G, is given by the user.
   e. The speed of light, c, which is given by the user.
   f. The initial kinetic energy, E_i, of the particle, is given by the user. It is set for all particles, regardless of color.

g. Positive mass will determine the matter characteristic of the particle and will emit:
    - a force of attraction of infinite radius, whose intensity decreases with the square of the distance, to particles of matter.
    - a repulsive force of infinite radius, whose intensity decreases with the square of the distance, towards antimatter particles.

h. The negative mass will determine the antimatter characteristic of the particle and will emit:
    - an attractive force of infinite radius, whose intensity decreases with the square of the distance, towards antimatter particles.
    - a repulsive force of infinite radius, whose intensity decreases with the square of the distance, towards matter particles.

i. When a particle of matter hits a particle of antimatter, they will annihilate each other. At the point of annihilation an energy equal to the conversion of the total mass to energy of the two annihilated particles will be generated for one time step. This is considered if the option in (8) is active.

8) **Spatial-temporal dilation**: increasing the velocity of the particle leads to an increase in its kinetic energy at increasing total mass. As the speed approaches that of light (c), the particle (which is a point) elongates and its apparent (not real) motion decreases (distance travelled per frame). When it reaches the speed of light (c) the particle becomes a stationary line (i.e., it does not move) as long as the simulation space and as thick as half the diameter of a point.

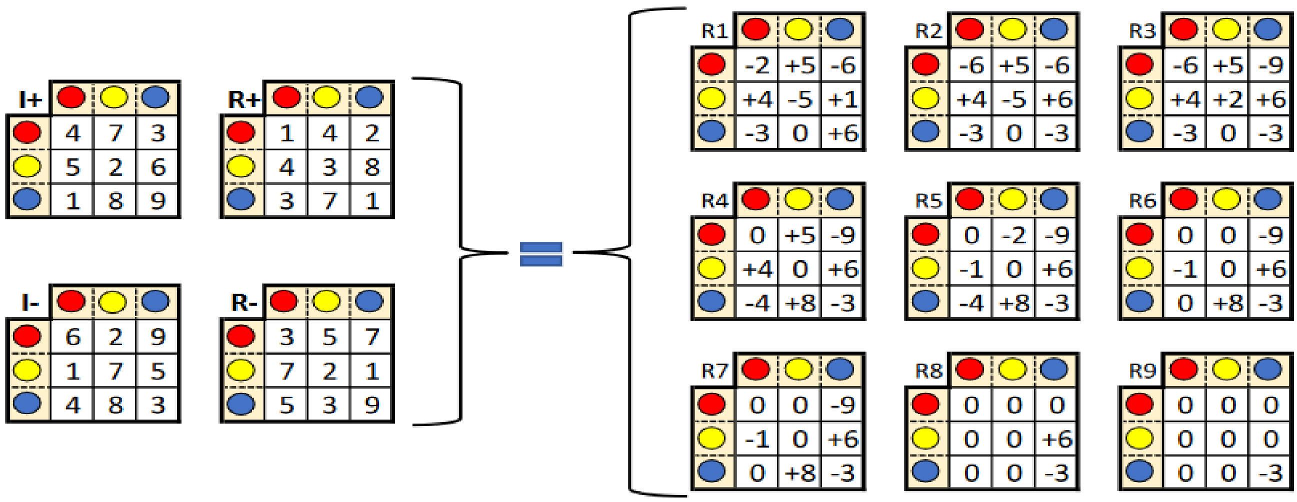
9) **Tidal forces**: These arise due to the difference in the gravitational field between the near and far sides of an object. To implement this effect, it should calculate the gradient of the gravitational field at the position of each particle.
Tidal forces are caused by the variation of gravitational force on different parts of a body. In the case of the Moon and the Earth, for example, the gravitational force of the Earth is stronger on the side of the Moon that is closer to the Earth and weaker on the side that is further away. This difference creates what is called a 'tidal force', which distorts the shape of bodies and causes phenomena such as ocean tides on Earth.
In the context of your simulation, if you want to include tidal forces, then you should calculate the variation of the gravitational field at the location of each particle. This could be done by calculating the gravitational field gradient.

10) **Precession effects**: Precession refers to the change in the direction of an object's axis of rotation over time. In the context of a particle simulation, this could be modelled by adding a rotational component to the motion of each particle. This could be achieved by introducing an additional force acting perpendicular to the direction of motion of the particle.
Precession is the change in the orientation of an object's axis of rotation over time. In the case of planet Earth, its axis of rotation is not stable but describes a conical motion, a phenomenon known as precession of equinoxes.
Gravitational precession refers to the change in an object's axis of rotation caused by gravitational forces. In the case of Mercury, for example, the precession of its orbit (i.e., the change in time of the point closest to the Sun in its orbit) is significantly influenced by general relativity.

In the case of a particle simulation, precession effects could be modelled by introducing a rotation component into the motion of each particle. This could be achieved by adding a force acting perpendicular to the direction of motion of the particle.

11) **Sequential Intensities**: The intensity is no longer constant over a given interval but varies over segments of the interval. Thus, the range of a force will be segmented into a user-defined number of segments, and the interaction between two types of particles will have intensities defined by a linear matrix. Along a segment, the intensity of the force will be constant, but may be different along different segments. Thus, each pair of particle types (colors) will have a matrix of sequential intensities, a linear matrix, in which each element represents the intensity of the force and its position in the matrix indicates the distance at which it has an effect. The user will define a maximum radius (distance) of the simulation, Rmax, and this will determine the number of elements of the interaction matrix. If we have a radius of 300, and the number of sequences is 10, then each sequence will have an interval of 30 during which the intensity will remain unchanged. The intensities will have a sign, the positive sign representing attraction and the negative sign representing repulsion. If, for example, we set Rmax = 5, then we can have an interaction matrix between red and blue like this: R-B = (+2, +3, -4, -2, 0). This means that if a blue particle comes within range of a red particle, the red particle will exert a repulsive force (given by the - sign) of intensity 2 over the distance from 3 to 4, a repulsive force of 4 over the distance from 2 to 3, an attractive force (given by the + sign) of intensity 3 over the distance from 1 to 2 and an attractive force of intensity 2 over the distance from 0 to 1.

If we look at how we used to define intensities, they still formed a linear matrix for each color pair, but the values were constant over the range of the force, as we see in the picture below:



	0-R1	R1-R2	R2-R3	R3-R4	R4-R5	R5-R6	R6-R7	R7-R8	R8-R9	R9-∞
🔴🔴	-2	-6	-6	0	0	0	0	0	0	0
🔴🟡	+5	+5	+5	+5	-2	0	0	0	0	0
🔴🔵	-6	-6	-9	-9	-9	-9	-9	0	0	0
🟡🔴	+4	+4	+4	+4	-1	-1	-1	0	0	0
🟡🟡	-5	-5	+2	0	0	0	0	0	0	0
🟡🔵	+1	+6	+6	+6	+6	+6	+6	+6	0	0
🔵🔴	-3	-3	-3	-4	-4	0	0	0	0	0
🔵🟡	0	0	0	+8	+8	+8	+8	0	0	0
🔵🔵	+6	-3	-3	-3	-3	-3	-3	-3	-3	0

12) **Sequential probabilities**: The intensity of the forces on each range will also have a certain probability. If for example we set $R_{max} = 5$, then we can have a matrix of interactions between red and blue like this: R-B = (+2, +3, -4, -2, 0), and the R-B interaction will have a probability of 0.20. In addition, the interaction forces on each interval will have the following probabilities: (0.30, .023, 0.40, 0.80, 0.10). This means that if a blue particle enters the range of action of the red particle, the interaction between them will have a probability of 20% and if it meets, the red particle will exert a neutral force (given by the sign of 0) of intensity 0, with a probability of 10% and a repulsive force (given by the sign -) of intensity 2, with a probability of 80%, over the distance interval from 3 to 4 and a repulsive force of 4 with a probability of 40% over the distance interval from 2 to 3 and an attractive force (given by the + sign) of intensity 3 with a probability of 23% over the distance interval from 1 to 2 and an attractive force of intensity 2 with a probability of 30% over the distance interval from 0 to 1.

13) **Sequential viscosities**: The viscosity is no longer the same over the entire range of an interaction between two colored particles but is also variable over each range. Thus, this distributional viscosity is given by a linear matrix. For example, if we consider the R-B interaction, it has a matrix of sequential intensities (+2, +3, -4, -2, 0), a matrix of sequential probabilities (0.30, 0.23, 0.40, 0.80, 0.10) and a matrix of sequential viscosities (0.75, 0.60, 0.80, 0.90, 0.65).

14) **Evolutionary Parameters**: All simulation parameters can change over time. Each parameter (intensity of each type of force, range of each type of force, probability of each type of interaction, viscosity of each type of interaction, etc.) has a certain probability to increase or decrease by a certain user-defined percentage at each time step. Even the functions defining the intensities of the interaction forces have a certain probability of evolving, in the sense that they may increase or decrease by a certain user-defined percentage. The user will define a maximum value for the increase and a minimum value for the decrease for each parameter so that it does not evolve to values that can cause chaos in the simulation.

15) **Singularity**: When the kinetic energy density in a given region of space reaches a certain critical level E_s, i.e. critical mass density M_s, a singularity will form in the center of that region where the density is maximum, absorbing all particles within the Schwarzschild radius, and at the boundary of the Schwarzschild radius will create an event horizon drawn in the simulation as a thin white circle half the diameter of a point. This singularity will have a mass as large as the sum of the total masses of all the particles it engulfs. As its mass increases, the radius of the event horizon will increase, as shown by the Schwarzschild radius calculation formula. If a particle touches the event horizon, it becomes a line, but this line will become a circle because gravity bends light. The circle will coincide with the event horizon and will also be white. The singularity will be invisible, what you will see in the simulation will be just the white circle that marks the event horizon.

16) **Metaparticle**: Particles that enter a stable bond, as mentioned in (4), or that stick together (which is also a stable bond), form a group of particles. This group of particles acts as a single particle, called a metaparticle, and has the following characteristics and properties:

a. The group has a center of force, as the force resulting from the composition of the forces emitted by the component particles and their position in the group and in space.
b. The metaparticle is considered as a single entity and will have mass which will be the sum of the total masses of the component particles (including their kinetic energy).
c. The metaparticle will behave as a single particle, having motion, velocity, kinetic energy, mass, but will not exhibit colored forces towards other metaparticles, but only towards individual particles approaching it at a distance whereby any colored force emitted by the component particles acts.
d. The metaparticle will have an electrical charge, either positive, negative, or neutral.
e. The value of the electric charge is given by the sum of all the intensities of the attractive and repulsive forces of all the combinations of colors forming the metaparticle. For example, if a metaparticle consists of 2 red particles and one orange and one blue particle, then the electric charge will be calculated as follows:
f. R-O(a)*2 + R-O(r)*2 + R-B(a)*2 + R-B(r)*2 + O-B(a) + R-R(a).
g. Having electric charge, the metaparticle will emit a new force field, called electromagnetic force, which will manifest only and only between metaparticles, not between metaparticles and particles.
h. Metaparticles may form larger groups, but those will not be considered as a single metaparticle, but will be considered as substances, within which only electromagnetic forces will act.
i. There will be a viscosity between metaparticles, which will be given by the weighted average of the viscosities of the interactions between the colored particles forming them. For example, if metaparticle X consists of 2 red particles, a blue particle and a green particle, the average will be calculated as (2*(red-blue viscosity) + 2*(red-green viscosity) + (red-red viscosity) + (blue-green viscosity)) / (2+2+1+1).
j. Gravitational and electromagnetic forces, not colored forces, occur between substances.
k. So, only colored, and gravitational forces manifest between particles, only electromagnetic and gravitational forces manifest between metaparticles, and only gravitational and electromagnetic forces manifest between substances.
l. A concrete example can be found here: https://buddhaman.itch.io/tims-insane-meta-universe.

17) **"Wormholes"**: form if in each space the kinetic/mass energy density is at a certain level. When this critical level is reached, there is a probability "P_w" that a singularity or "wormhole" will appear at that point. The property of the 'wormhole' is given by its type:

a. "Unidirectional unipunct wormhole" - Has only one entrance and one exit, and any particle or metaparticle entering it exits at another point in space, but without being able to travel back and forth.
b. "Multipoint unidirectional wormhole" - Having a single entry and "n" exits, and any particle or metaparticle entering it exits at one of the n possible exits of this "wormhole", but without being able to travel to the other side of space. The probability is equal of exiting at either end of it.
c. "Bidirectional unipunct wormhole" - It has a single entrance that is also an exit and a single exit that is also an entrance, and any particle or metaparticle that enters it

exits at another point in space, but any particle that enters it at the other point in space can also exit at this entrance point, depending on its direction of motion.

d. "Multipoint bidirectional wormhole" - Several points in Riemannian space are connected to each other (i.e., coincide), and any particle or metaparticle entering at any of this point can exit with equal probability at any other point to which this point is connected. A particle once entered does not exit at the same time through that point, but through another point to which it is connected, keeping its direction of travel.

18) **Riemannian surfaces**: the user will be able to select the option of Riemannian surfaces for the simulation space. These surfaces are irregular manifolds that can be viewed in 3D or n-dimensional, although they are 2D surfaces. The reasons for introducing them are the following:
   a. These spaces may have holes, i.e., interrupted areas, where their edge leads to areas on the surface other than the neighboring one.
   b. Can be used in conjunction with options (8) and (9), where the singularity may break the space and create "wormholes", i.e., option (21).
   c. Reality is a Riemannian surface, so the simulation would be more realistic.

19) **Wrap space**: The user will have the option to turn the simulation space into a closed-ended space (i.e., a kind of toroid). Note that the particles separated on the screen by the edge areas of the simulation space are not actually separated, because the simulation space is closed and has no edges. Edges are only visual, and therefore particles at one edge must interact with those at the opposite edge with which they are actually and literally connected.

20) **Size of simulation space**: the user will have an option to set the size of the simulation space.

21) **Zoom size**: The user will have an option to set the zoom range in the simulation, zoom controlled by the mouse wheel, i.e., how far he can zoom out, and how far he can zoom in. He will also be able to set the zoom force (i.e., zoom speed).

22) **Shape of the simulation space**: The user will be able to choose a certain shape of the simulation space: square, rectangle, circle, hexagon, octagon, irregular (random).

23) **3D visualization of a 2D space**: If option (13) is also active, the circle space with the wrap option can also be visualized as the surface of a sphere that can be rotated with the mouse. The square space can be viewed as a cube rotated with the mouse. The same goes for the other surface shapes.

24) **Navigation of the simulation space**: The user will be able to navigate through the simulation space:
   a. Using the keyboard arrows.
   b. With the mouse.
   c. With the ADSW keys.
   d. If option (13) is also active, then you will also be able to "drag" with the mouse, i.e., be able to drag the space in any direction you want, to also view the border areas in the center of the screen.

25) **Run the simulation in the background**: The simulation can run several user-defined time steps t_s in the background and will save each time step to a file. Later, the user will load the saved file into the interface and will be able to run the simulation to see each time step like a movie.

26) **Saving all simulation parameters**: The user can save and load later all parameters of a simulation with or without the current simulation step.

27) **Print screen + Record**: The user can take a screenshot of the visible simulation space or the whole simulation space and automatically save it to a *.png or jpg file. He can also record a movie of the simulation run and save it as mp4 or *.mkv.