# Negative Mass as a Driver For Cosmic Inflation, Dark Energy and Dark Matter

## Abstract

I have conducted n-body simulations of a model universe. Initial conditions include a uniform mix of 4 types of particle: positive and negative charge and positive and negative mass. A "cold collapse" scenario is used, except that only parts of the model collapse, the rest expands. I contend that this is compatible with the known universe and a viable solution to the Dark Energy puzzle.

Also discussed is a possible solution to the Dark Matter puzzle. This relies on the self-attractive effects of negative mass.

## Motivation

In 2009 I was sat in my proverbial armchair reading astronomy magazines and the like. I resolved to do something about it and contribute something to the internet rather than just reading about it. As luck would have it I found www.artcompsci.org [1] fairly quickly and began translating their n-body code from Ruby to C++, this being my area of expertise.

To begin with I just stuck with standard physics and did not make major alterations to the code. I made some minor improvements and 9 months later was ready to publish it on a website of my own www.grav-sim.com [2]. It didn't take long for the professors to find it and I entered into a dialog with Piet Hut, with me doing 2 online presentations at the "Meta Institute of Computational Astrophysics" and a face-to-face presentation at Leiden University.

At this stage my curiosity had started to take hold and I wanted to know what happened if I plugged in negative numbers for masses. None of the astrophysicists were interested.

So I resolved to go my own way and see where it led. I found out that Grav-Sim was absolutely fine with negative numbers. The only parts of the code that failed were the optional Barnes-Hut accelerator and the like that I'd added as a performance improvement. They gave division by zero in center-of-mass calculations where the total mass was zero. This was a small sacrifice.

Beyond that I wanted to find out how far I could go in simulating the real universe. I realised that Grav-Sim as it stood was limited by the fact that you could model positive or negative and that was it. There was no distinction between gravitational and inertial mass.

Likewise I read 3 papers by Don Hotson in Infinite Energy magazine where he talked about Dirac's equation, the sea of negative energy and the 4 electrons that are the result. I realised there was no difference between what Don was proposing in electrostatic terms and what I was proposing in gravitational terms. The software would be the same either way.

This led to me publishing another website of my own www.dirac-was-right.com [3] and I explored as far as I could without actually building the software. This was in 2013.

Finally I actually went ahead and built the software to conduct gravitational / inertial mass or electrostatic simulations in 2018. When I did so, I was surprised to find that seemingly all initial model universes with a mixture of positive and negative mass expand overall. This led me to write this paper.

## Hypothesis

Consider the Coulomb law of electrostatic force:

- $F = Ke\ q_1\ q_2 / r^2$

Coupled with Newton's second law of motion:

- $F = m\ a$

I can choose a system of units such that the leading constant Ke is 1.

Beyond that I can make a generalisation to accepted practice by allowing the mass m to take on the values +1 and -1. This gives us 4 kinds of "electron" to consider, in Table 1:

| Particle | Charge | Mass | Self Interaction |
|---|---|---|---|
| Ae | +1 | -1 | Attract |
| Be | -1 | +1 | Repel |
| Ce | -1 | -1 | Attract |
| De | +1 | +1 | Repel |

**Table 1: The 4 Particles**

I've labelled them Ae,Be,Ce and De for convenience. At a glance, Be and De can be seen as the conventional electron and positron respectively. Ae and Ce are newcomers.

Actually I can also do the analysis with protons, in which case I get Ap,Bp,Cp and Dp with mass = +-1836. In this case Dp is the conventional proton and Bp is the anti-proton. Ap and Cp are newcomers. The analysis works out the same.

Now I can draw up a chart of how they interact with each other, in Table 2:

| Particle | A | B | C | D |
|---|---|---|---|---|
| **A** | Attract | Combine | Repel | Combine |
| **B** | Combine | Repel | Combine | Attract |
| **C** | Repel | Combine | Attract | Combine |
| **D** | Combine | Attract | Combine | Repel |

**Table 2: Particle Interactions**

There are 3 types of behaviour. Attract and Repel are well known. The 3rd type Combine is a case where 2 particles of combined mass zero accelerate in the same direction, remaining the same distance apart (subject to relativity). This has been analysed as Runaway motion in the literature before, notably in [4] and [5], so I will go no further here.

Suffice it to say that the newcomers bring, at an electrostatic level:

1. Self Attraction
2. Repulsion of Each Other
3. Runaway Motion in 50% of Cases

My hypothesis is that the 1st point is a driver for Gravity and Dark Matter while the 2nd and 3rd points are drivers for Cosmic Inflation and Dark Energy.

I aim to make my points by running a computer simulation of a model universe which contains both positive and negative mass.

# Method

A standard gravitational n-body simulator Grav-Sim [2] was available as a suitable starting point. This was based on [1].

In order to make the necessary changes, I had to introduce a concept of Gravitational Mass as distinct from Inertial Mass. Given the system of units and leading constant of 1, Newton's Law of Gravitation may be seen as equivalent to Coulomb's Law of Electrostatics, with the mapping:

- Charge ~= Gravitational Mass
- Mass ~= Inertial Mass

Grav-Sim already copes with the concept of negative mass so no specific changes were required there. This was the deciding factor in choice of system. Effectively I have built an electrostatic simulator (capable of negative mass) starting with a gravitational simulator (capable of negative mass).

The target was to run simulations of 1,000-10,000 bodies on very modest hardware, namely a dual core laptop bought in 2018.

The initial conditions are auto-generated to fit a uniform random distribution within a sphere of radius 1.0. The distribution is initially cold meaning everything has velocity zero. This is at odds with hot big bang scenarios; the rationale is that the mixture of positive and negative mass generates more than enough by way of expansion that a standing start is entirely sufficient.

The question of baryogenesis is addressed. An equal mix of positive and negative charge is assumed, notwithstanding the apparent lack of antimatter in the observed universe. Furthermore, I double down by having an equal mix of positive and negative mass. Finally I simulate 2 mass quanta, namely that of the electron (1) and the proton (1836). I use an equal mixture of these too.

The results may be viewed in 3D as a distribution of coloured points. Or alternatively they may be sent through an algorithm that generates a Newick Format tree based on minimum collision timescale. Then the structure of associated groups of particles may be inspected.

The instructions for installing the software provided are as follows:

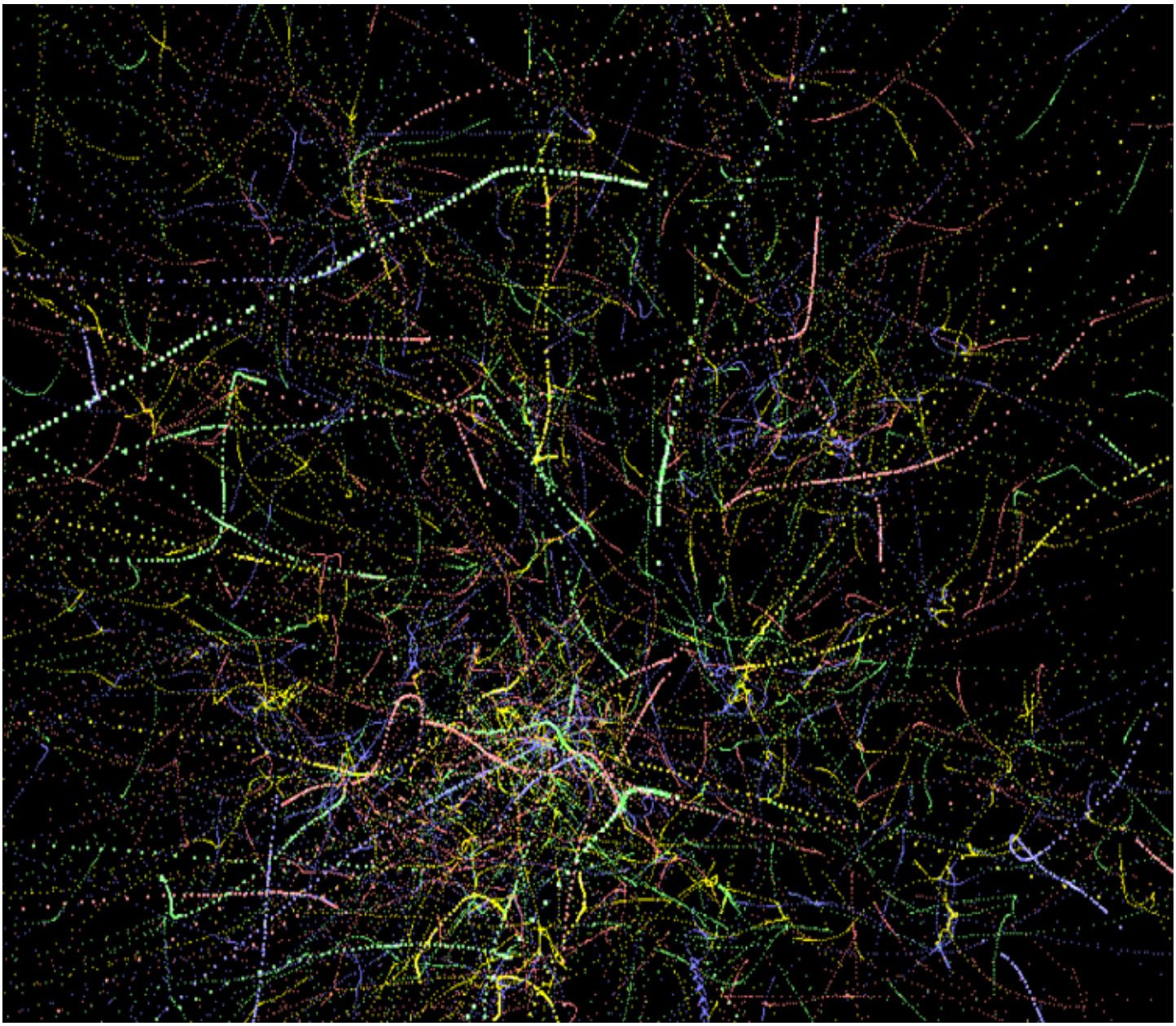
- Download the file dirac-was-right-0.1.zip from [6].
- Select the appropriate Makefile.inc.xyz for your machine and replace Makefile.inc in the top level directory
- > make clean
- > make
- This should leave executables in the top-level directory

Then operating the software is as follows:

- > GravSim -g uniform -s mixture -b 1000 -r model1000.csv
- > GravSim -f model1000.csv -m 1.0 -r result1000.csv
- > GravSim -f result1000.csv -t constant -n on -r newick.txt
- > GravView -f result1000.csv
- Load newick.txt into [7]

# Results

The evolution over timescale 0.0 to 1.0 took 1 hour for 1,000 bodies or 100 hours for 10,000 bodies. This was using the leap-frog integrator in brute force $O(n^2)$ mode. The other steps were more or less instant.



GravView can be used to deduce that 90% of the bodies remain within a sphere of radius 2,0 with 99% inside 10.0. This shows a clear expansion of the overall universe.

Other parts of the universe have contracted into highly charged regions.

The website for viewing the Newick Format results newick.txt will cope with a file size of 1000 bodies but it doesn't cope very well beyond that.

The most noticeable thing from an inspection of the Newick results is that the four types of particle A,B,C and D sort themselves into nearest-neighbour groups. Given that B and D repel themselves, there must be some pressure via a potential well (or hill) to achieve this. Therefore this occurs in the areas of contraction rather than the overall area of expansion where there is negative pressure.

According to the rules of attraction / combination, I should see multiple pairs of AA, CC, BD, AB and CD forming. This is exactly what I see in the results. I do see some occasional BB, DD and AC but these are expected to dissociate over a longer timescale.

The Newick Format results are available at newick.txt [8]

I will focus on just a couple of fragments to give a flavour of what happens:

1. (Be,(Be,(Dp,(Bp,Dp))))
2. (Ae,(Ae,(Ae,(Ae,(Ae,(Ap,Ap))))))

The 1st fragment shows 3 protons surrounded by 2 electrons, all a mixture of B and D. Note that in this mini universe B and D simply orbit each other, they don't annihilate. Thus this simulation may be understood as each particle standing in for gazillions of real particles of the same basic type. Also note that the overall charge is roughly zero.

The 2nd fragment shows a typical result from these simulations which is that types A and C club together under their own attraction. Again it shows protons surrounded by electrons, which is what we would expect from the mass ratio. Note that these areas are highly charged. This is one of the main results of the simulation, where we see self-attraction beyond what we're used to with gravity.

## Conclusions

The relatively simple simulation conducted shows some interesting results.

The large-scale expansion is driven by the repulsive effects of negative mass and runaway motion in positive / negative combinations. This agrees with the hypothesis that it could be a driver for Cosmic Inflation and Dark Energy.

The smaller-scale contractions are driven by the attractive effects of negative mass where likes attract and opposites repel. Note that this is the opposite of what I usually see with electromagnetism. This agrees with the hypothesis that it could be a driver for Dark Matter

## References

[1] Piet Hut and Jun Makino, "The Art of Computational Science", http://www.artcompsci.org, 2006
[2] Mark Ridler, "Grav-Sim", http://www.grav-sim.com, 2009
[3] Mark Ridler, "Dirac-Was-Right", http://www.dirac-was-right.com, 2013
[4] Hermann Bondi, "Negative Mass in General Relativity", Reviews of Modern Physics, 29 (3):423, 1957
[5] Robert L Forward, "Negative Mass in Propulsion", Journal of Propulsion and Polr, 6:28, 1990
[6] Mark Ridler, "Source Code", http://www.dirac-was-right.com/downloads/dirac-was-right-0.1.zip [7] Phylogenetic tree (newick) viewer, http://etetoolkit.org/treeview/
[8] Mark Ridler, "Newick Results", http://www.dirac-was-right.com/newick.txt, 2018