Gravity As A Unified Force

Model A (Attractive)

Consider a unified model universe of particles where the only force acting between them is Gravity.

Newton's laws of motion apply at slow speeds, while Special Relativity enforces a global limit at the speed-of-light.

Assuming low speeds, Newton's law of gravity states:

$F = - G\, m_{g1}\, m_{g2}\ /\ r^2$

For the sake of simplicity, we'll assume that G = 1 from here on.

Newton's Second Law of Motion states:

$F = m_i\, a$

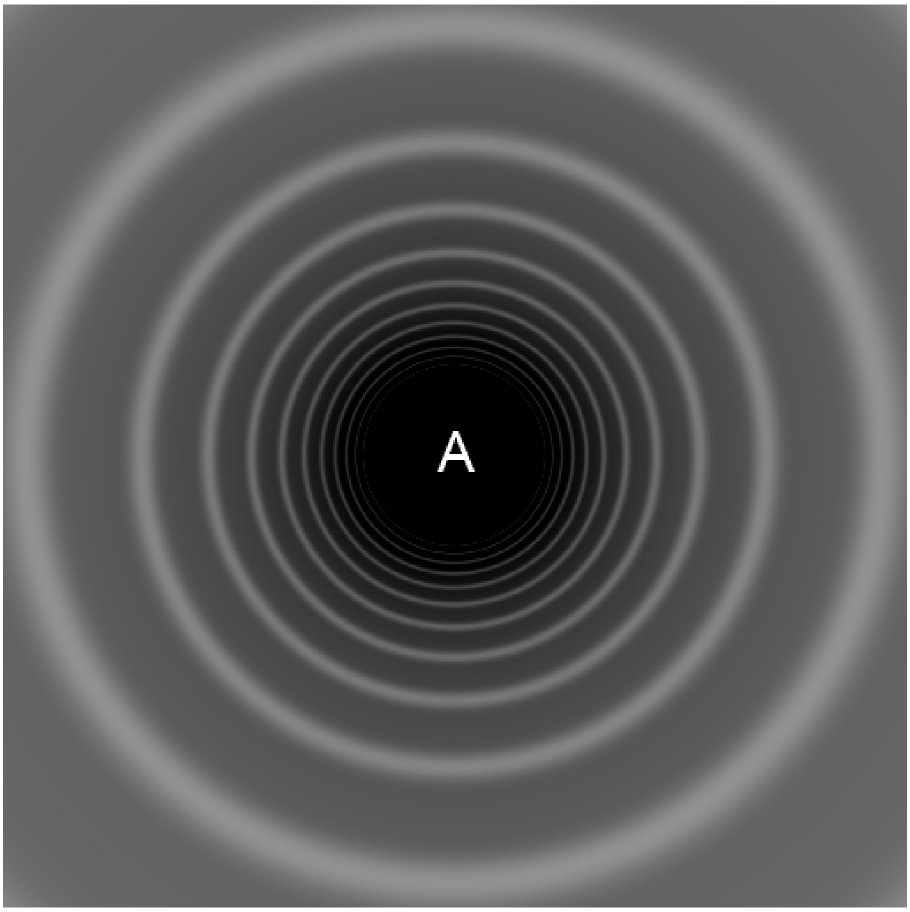
In standard physics, all masses are constrained to be positive. This leads to a universe where gravity is always attractive, which was bascially fine before 1998.

We can further simplify things by assuming that all particles in our model have the same mass m = 1. This means that all particles are essentially the same and we can give them the same label "A".

1-Body Problem

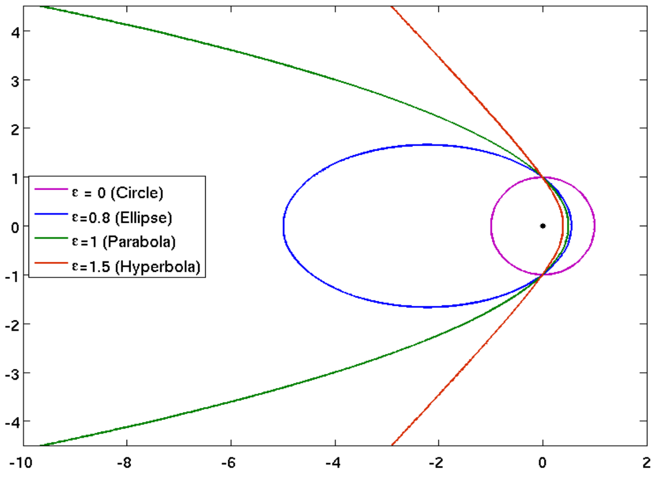
If we consider a single particle (or "body") of type A, then it either sits still or moves in a straight line according to Newton's first law of motion.

In particular, we can make a plot of the Gravitational Potential versus distance. Using the convention that higher potentials are plotted in lighter shades and lower potentials in darker ones, we get (with lines of equal potential):



We can think of the lines as a bit like a "marble run" to give us an idea of how other particles would behave if they were introduced into the system. This leads us neatly onto the next section...

2-Body Problem



We can analyse what happens when 2 particles of type A attract each other due to the force of gravity. This is known as the 2-body problem.

They behave in a familiar way, either colliding, orbiting around each other according to Kepler's laws of planetary motion, or flying past each other if their relative speed is high enough.

The shape of each orbit is one of:

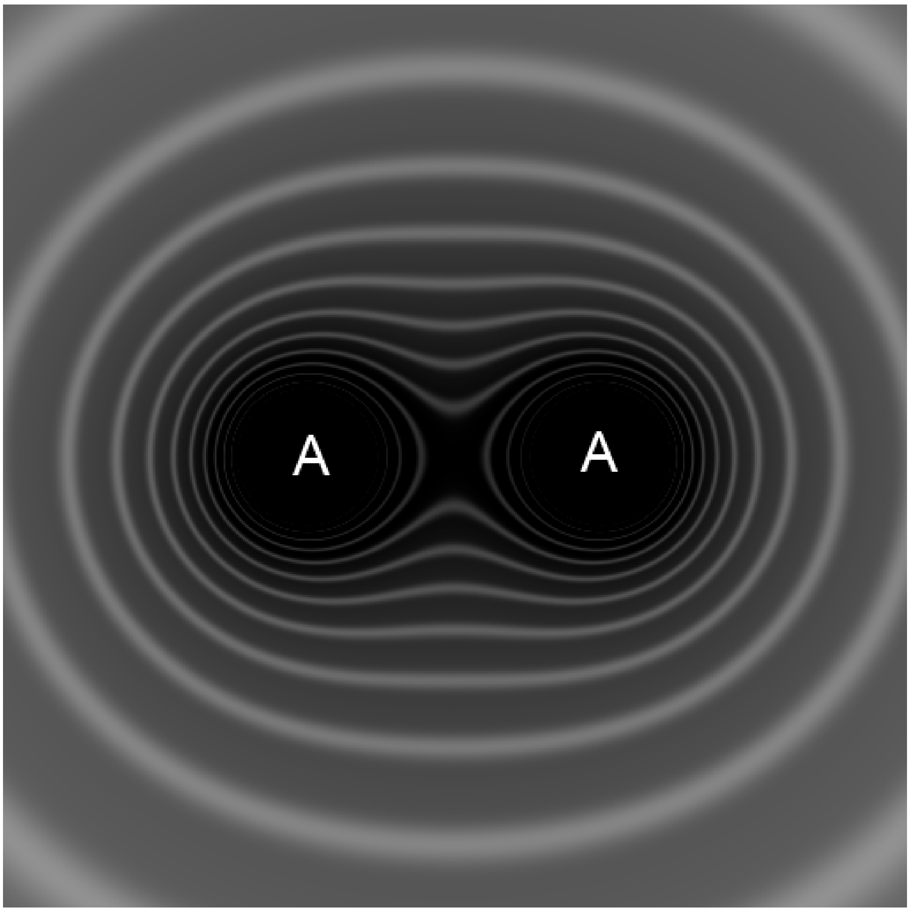
- Straight line
- Circle
- Ellipse

- Parabola
- Hyperbola

depending on their initial positions and velocity:

Note that because the mass of each particle is the same, they each move in a similar way due to the gravitational attraction from the other. Another way of expressing this is via Newton's third law of motion which states that "for every action, there is an equal and opposite reaction".

Again we can make a plot of the gravitational potential to get an idea of what their combined gravitational effect would be on other particles:



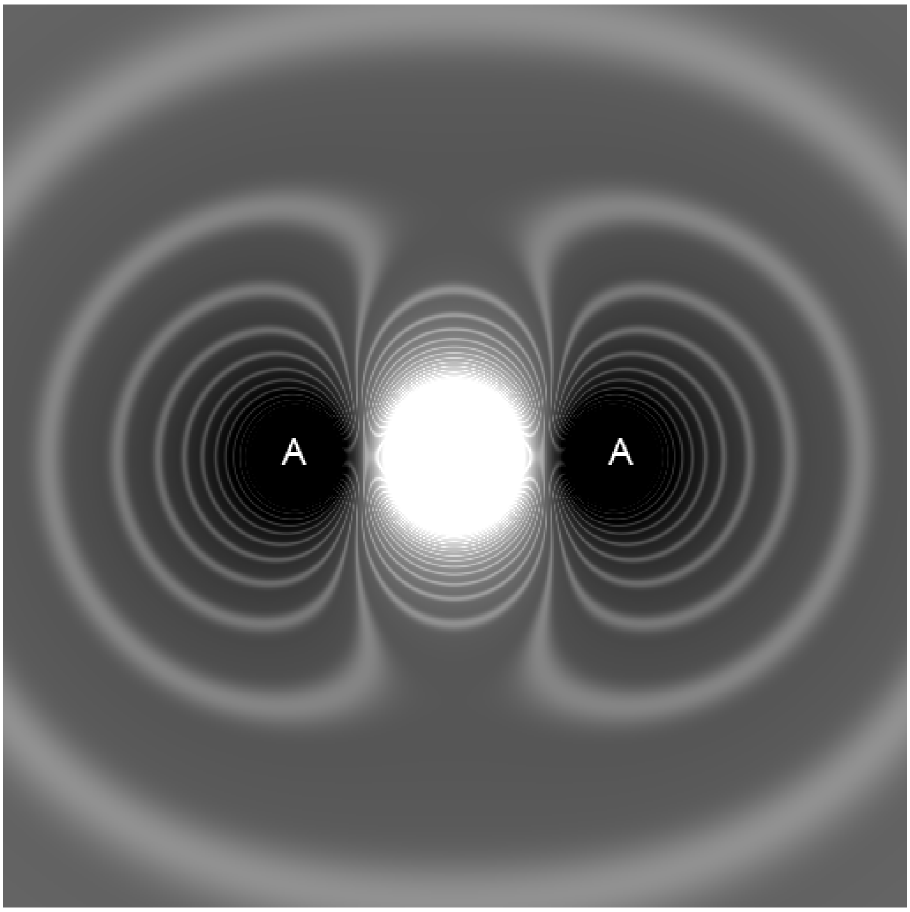
This shows us what the environment would be like around a binary star, for example.

3-Body Problem

Things get more involved as soon as introduce a 3rd particle. It turns out that it is not possible to solve this problem analytically and so we must resort to numerical methods (i.e. computer simulation) to find out what happens in the general case.

Nevertheless, we can get a flavour of what goes on if we start with just 2 of the particles and consider the environment around them, as experienced by the 3rd particle.

With 2 particles we can assume that they will be rotating around each other in the general case. If we measure things relative to the rotating frame then there is is also a rotational potential as well as the gravitational potential from the other 2 particles:



Effectively, a 3rd particle experiences the rotating frame as a repulsion away from the centre point, at the same time as still being gravitationally attracted to the other 2 particles. This is commonly known as Centrifugal Force.

This tells us that if it's sufficiently far away from the first 2 then the 3rd particle might orbit around them as if they're a single combined A particle with twice the mass, located at the centre point.

On the other hand, if the 3rd particle approaches either of the first 2 or flies between them near the centre, then the resulting collision or a near miss can send them in all sorts of directions, disrupting whatever was going on beforehand.

n-Body Problem

We can introduce yet more particles of type A, all of which attract each other gravitationally.

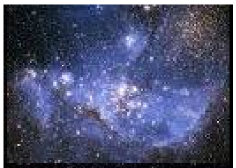
Some restricted cases may be analysed such as the Solar System or Moons of Jupiter.

In the general case there is little that can be done to study n-body systems analytically, but they are amenable to computer simulation, using readily-available software such as Grav Sim.

There are many examples of star systems that are essentially "stable", give-or-take the occasional close-encounter which results in the ejection of a star at high speed.

These systems can be found at a wide variety of scales:

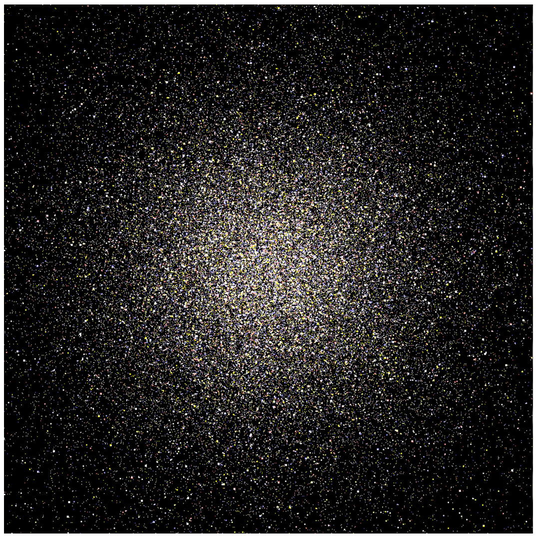
System	Number of Bodies	Example	Image
Open Clusters	10-1k stars	Pleides	
Globular Clusters	10k-1m stars	Omega Centauri	

Dwarf Galaxies	10m-100m stars	Small Magellanic Cloud	
Galaxies	1b-100b stars	Andromeda	
Galaxy Clusters	10-10k galaxies	Virgo Cluster	
Superclusters	10-1k clusters	Coma Supercluster	

At the Galaxy scale and above we find that there seemingly isn't enough matter there to hold everything together in purely gravitational terms. This is the problem known as Dark Matter.

Furthermore, at the scale of the entire universe, we find that gravity seemingly isn't attractive at all, but rather is repulsive. This is the problem known as Dark Energy.

Computer Simulation



All of the above can be simulated on a home computer using standard physics. A good place to start to understand the calculations can be found here, courtesy of Professors Piet Hut and Jun Makino.

You can even download some PC software from Grav-Sim, courtesy of the author. Included are some ready-made models of globular clusters, which you can use as a starting point.

For example, an artificially-generated cluster with 10,000 stars appears as follows:

Summary

Although we can get a long way with Model A and always-attractive gravity, we find that there are cases where it breaks down. In particular, it cannot model any situation where the bodies are repelled by each other, as appears to be happening at the largest scales in the universe.

Conversely, if we attempt to use it as a unified model at the smallest scales then it's a non-starter because Electrons - the very first sub-atomic particles discovered by J.J. Thomson in 1897 - repel each other.

Model AB (Attractive vs Repulsive)

Clearly in order to use a unified model of gravity as an explanation for everything that goes on in the universe, we will need both attractive and repulsive elements.

It turns out that it's a relatively simple matter to achieve this, starting with the always-attractive Model A and relaxing the constraint about masses being positive.

We can stick with Newton's law of gravitation and his second law of motion.

To keep things simple, we can still constrain the magnitude of the masses to be 1, but this time the sign can be either positive or negative.

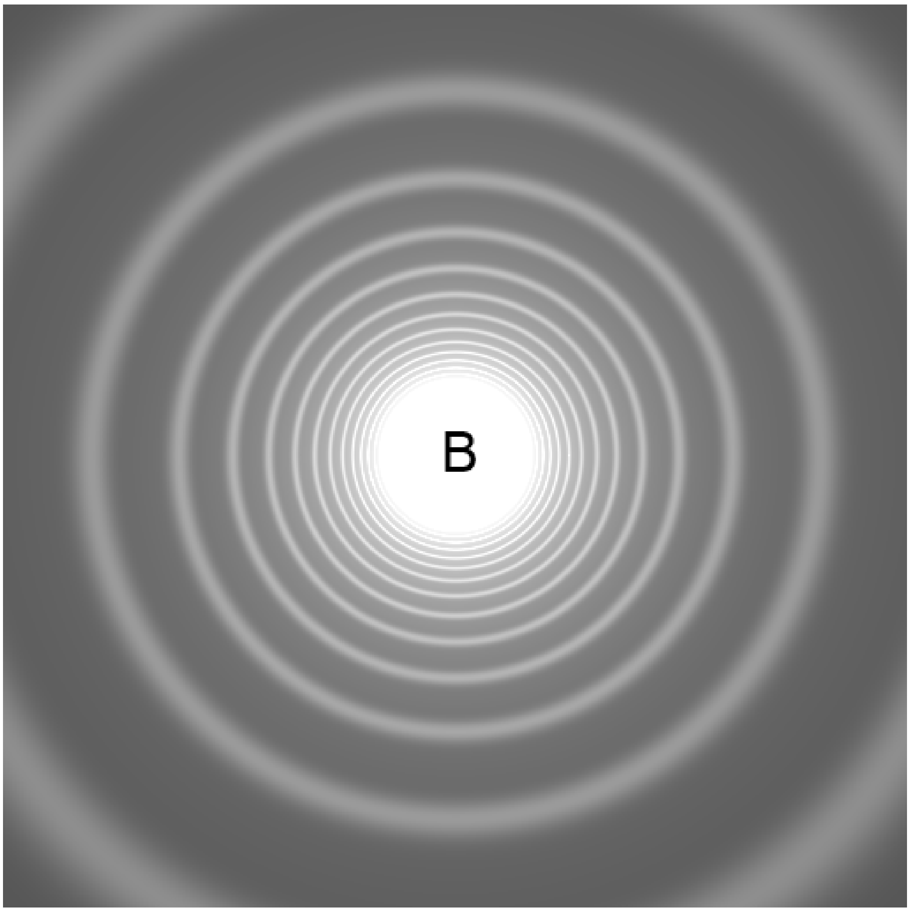
We can keep the label A for particles with mass +1 and introduce the label B for particles with mass -1.

1-Body Problem

Clearly the 1-body model for a particle of type A is the same as before and is always attractive.

Note that if we do the maths, we find that particles of both types A and B respond in the same way to the presence of a gravitational field and are attracted, so there is nothing more to say about the 1-body model for type A.

In contrast, the 1-body model for a particle of type B has the opposite sign and is always repulsive:



Because particles of both types A and B respond the same way, everything is repelled by a B particle.

We note that B particles repel each other according to an inverse square law, so we can imagine them as Electrons, to a first approximation.

2-Body Problem

Things start to get more interesting when we consider the 2-body problem. Because there are now 2 distinct fundamental types of particle, there are 4 possible 2-body interactions for us to analyse. If we do the maths, we get:

Interaction	A	B
A	Attract → ←	Combine ← ←
B	Combine → →	Repel ← →

Attract

The AA pair is the same as before, with straight-line, circular, elliptical, parabola and hyperbola orbits.

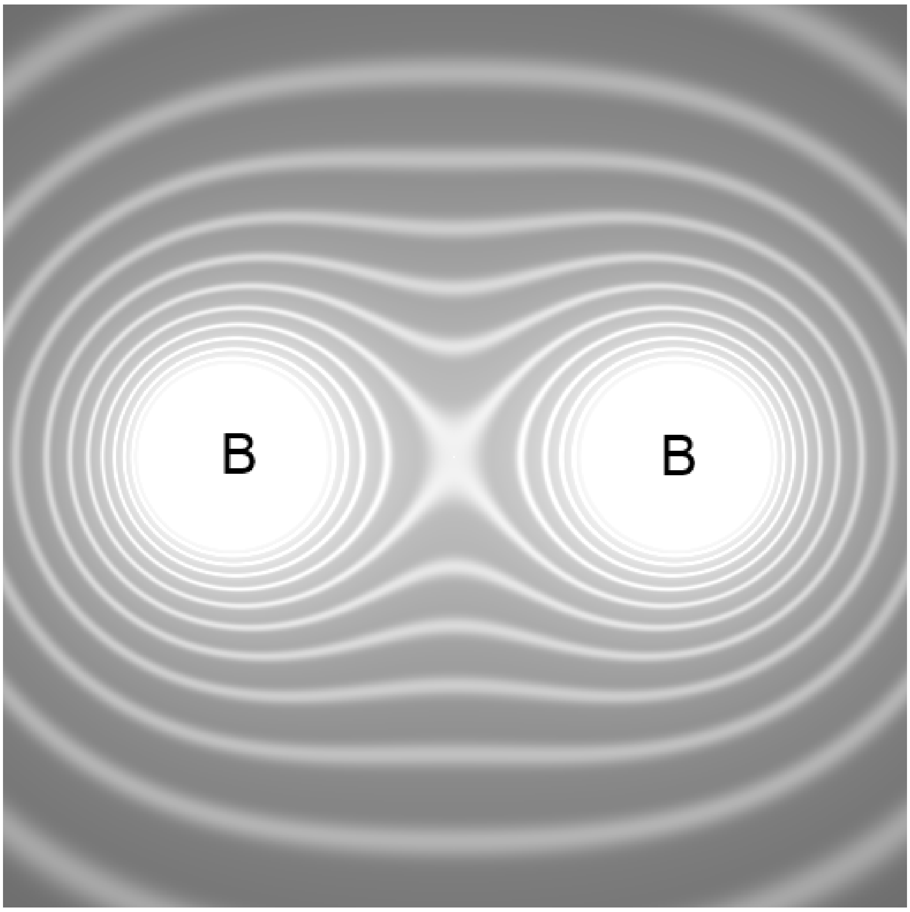
Repel

The BB pair can be analysed with essentially the same mathematics and we find that the circular and elliptical orbits no longer apply. Instead, the particles move in one of:

- Straight line (directly towards or away from each other)
- Parabola
- Hyperbola

In particular, these are mathematically the same parabolic and hyperbolic solutions as before, but we're now using the negative part of the curves whereas previously we were restricted to just the positive part.

In the general case, because a pair of B particles are likely to be moving away from each other, it makes sense to view the gravitational field in a non-rotating frame:



Combine

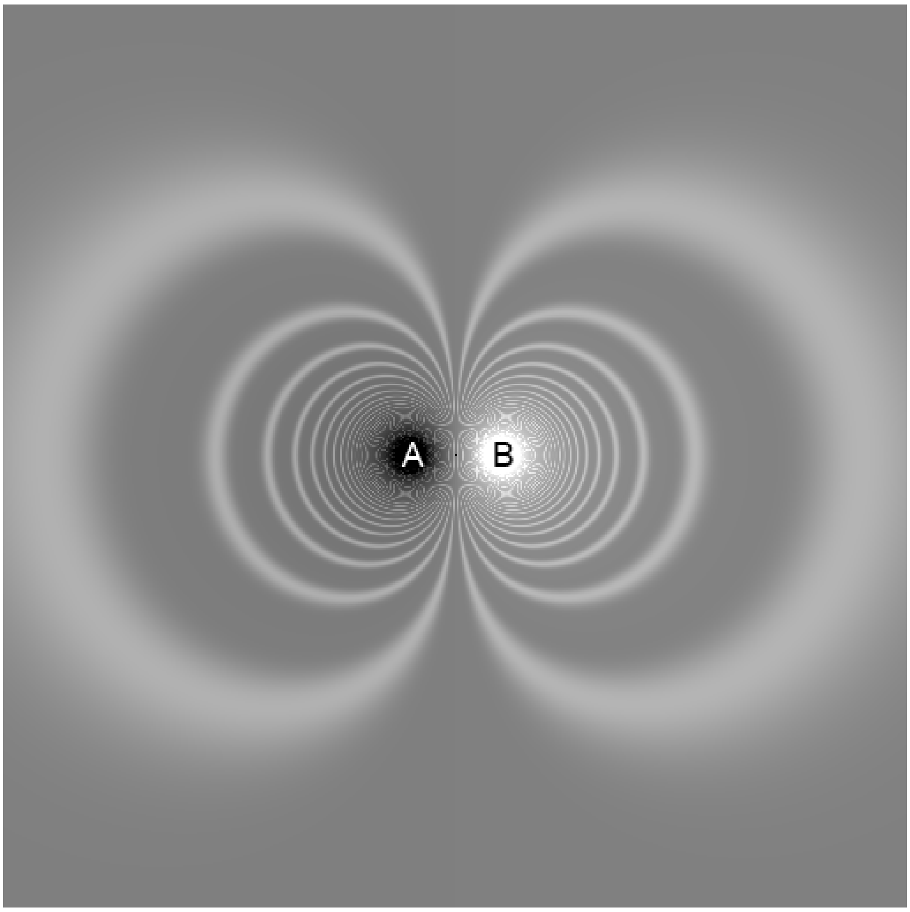
For cases AB and BA (which are just mirror images of each other), we find a new type of behaviour.

If we do the maths, we find that B is attracted to A at the same time as A is repelled by B. Essentially, they accelerate at a constant speed in a straight line, always remaining the same distance apart.

This continues until Special Relativity starts to take effect at high speeds and the particles approach the speed of light, without ever quite getting there.

Likewise, Length Contraction causes them to move closer together at high speed, as seen by a stationary observer.

Again, it makes sense to view the gravitational field around an AB pair in a non-rotating frame:



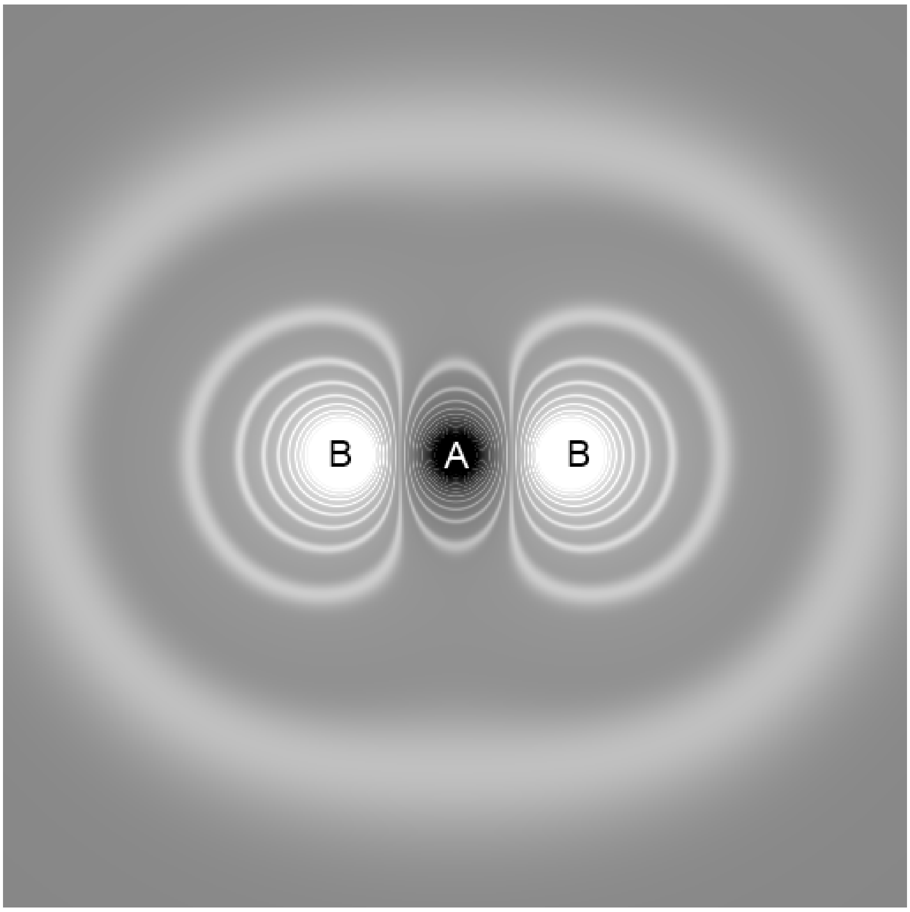
In terms of relating this to known phenomena, clearly we don't see this behaviour at the macroscopic scale. Real-world objects simply don't pair up and hare off at the speed of light...

We can make the following observatioms though:

- The combined mass of A and B is zero
- They are unlikely to be observed travelling at anything other than the speed of light
- They have a characteristic length governed by their initial separation, which is preserved (subject to length contraction)
- The long-range gravitational effect on anything else is effectively zero
- The short-range effect manifests itself as a gravitational dipole, in the direction of motion
- This can be thought-of as a quantum of a longitudinal gravitational wave
- It is likely that A will be in the lead followed by B (i.e. has a characteristic polarity)

3-Body Problem

The case of a BAB combination presents a very interesting new scenario, where the 2 B particles are in a stable orbit around the central A. By looking at the gravitational field in a non-rotating frame:



We can see that at long-range, it looks very much like a single B particle, whereas from close-range the attractive vs repulsive aspects start to take effect. On average we see an increased repulsive effect at short range before the attractive effect becomes apparent at very close range.

Is this a plausible explanation for the experimental result that electron repulsion increases by roughly 10% at very close range, compared to the inverse square law? This would imply that contrary to commonly-accepted wisdom, the electron is a composite particle after all.

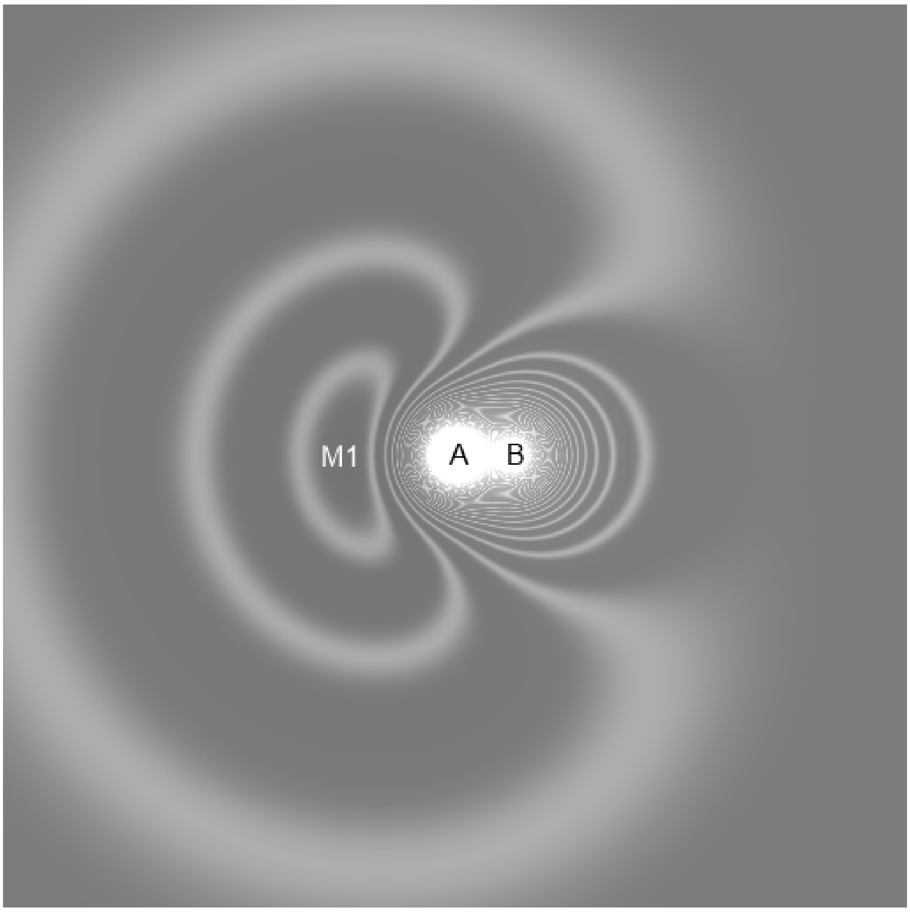
Is it also possible that this kind of situation could provide an explanation for the Strong and Weak forces? Although all interactions may be subject to the same unified force, the existence of composite particles with varying components could make it appear as though one force takes effect at long range with another one at short range.

Although the central A is repelled by the pair of orbiting Bs, it is effectively sandwiched in the middle and so unable to go anywhere. To a first approximation, it makes little difference whether the A is attracted to or repelled by the Bs.

We can think of this as a bit like a pair of electrons orbiting around an atomic nucleus. Because the electrons repel each other, they act to keep the nucleus in the middle and to ward off any intruders.

Simulation of Helium$^+$

Picking up on this theme, we can take a closer look at what happens when the masses vary. For a central A particle with the mass of a helium nucleus and a single B particle with the mass of an electron, in a rotating frame:



We can clearly see that there is a point M1 near which a second B particle would be stable. This starts to give us an idea of how a pair of electrons could behave in an atomic orbital, in purely inverse-square-law (i.e. electrostatic) terms.

In particular, this is the opposite scenario compared to the Lagrange Points with the Sun and Earth, because the 3rd particle is repelled by rather than attracted to the 2nd one.

Summary

Model AB certainly allows us to simulate much more of the universe compared to Model A. In particular, the repulsive element introduced by the negative-mass B particle gives us a plausible mechanism for explaining Dark Energy.

We indentified 3 cases where the individual particles can behave together as a composite particle:

Composite Particle	Gravitational Mass m_g	Inertial Mass m_i	Location
AA	+2	+2	Stable
AB	0	0	Light Speed
BAB	-1	-1	Stable

The AA pair behaves like a binary star and is stable in either a circular or elliptical orbit.

If we were to start speculating a little, we could say that the properties of the AB composite particle make it look a bit like:

- Gravitational Wave (hypothetical, has never been observed in practice)
- Neutrino (except that we haven't accounted for the spin-half property)
- Photon (except that a photon has a transverse electromagnetic component)

Furthermore, whichever interpretation we go with, we can imagine AB travelling at the speed of light through the quantum vacuum. On occasions where A or B particles arise from the vacuum, AB can react with them, but typically still carries on going, even though its consituents have changed places.

In the case of the BAB composite particle, we note that its overall properties appear to be identical to a single B particle. We can think of it as a bit like a B that has absorbed an AB.

There are still many aspects of the real universe that Model AB fails to deal with though. In particular, from the laws of electromagnetism:

- Opposites Attract
- Likes Repel

Neither of these can be catered for with Model AB (where opposites combine and only Bs repel).

In particular, Protons were discovered by Ernest Rutherford in 1920 and are known to repel each other while being attracted to electrons.

This means that at this stage, our unified approach is unable to model electrons and protons at the same time, even to a first approximation.

Clearly we need something extra.

Model ABCD (Likes vs Opposites)

By sticking with gravity as our single unified force, restricting the magnitude of all masses m = 1, yet allowing positive vs negative mass and introducing separate concepts of gravitational mass m_g and inertial mass m_i, we get the following:

Particle	Gravitational Mass (m_g)	Inertial Mass (m_i)
A	+1	+1
B	-1	-1
C	-1	+1
D	+1	-1

The A and B particles behave the same as before, so the interesting part comes from studying the newcomers C and D. We can think of these as opposites or mirror images of A and B, a bit like Antimatter compared to Matter.

The first thing to do is to draw up a chart of how the particles interact with each other:

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 ← →

We can think of the B particle as a bit like an Electron, given that they repel each other.

On the basis that opposites attract, this would make the D particle a Positron.

Note that it doesn't matter whether we assign B or D as the positive or negative charge. This is just a convention and the maths works equally well whichever way round we choose.

This makes B and D suitable for simulating electromagnetic particles, at least in electrostatic terms.

Conversely, A and C have the opposite behaviour, where likes attract and opposites repel.

The A particle remains suitable for simulating standard gravity, whereas we expect the C particle to be its antimatter equivalent.

We note that C particles are attracted to each other, just the same as A particles. This means that if the C particle really is a good way of thinking about antimatter in gravitational terms then we would expect it to be repelled by matter.

This is the first prediction that we can make from our unified model. In gravitational terms, we expect antimatter to be repelled by matter, while still being attracted to itself. We therefore predict that the CERN experiments will confirm that Anti-Gravity is possible.

3 Binary Pairs (Cold)

In much the same way as stars frequently form binary pairs due to the attraction of gravity, we would expect a universe full of As, Bs, Cs and Ds to generate binary pairs in cases where the mutual force is attractive.

From the interaction table above we can identify 3 such cases:

Binary Pair	Gravitational Mass m_g	Inertial Mass m_i
AA	+2	+2
CC	-2	+2
BD	0	-2

In each case the pair can be stable on an indefinite basis if the orbit is circular or elliptical.

We note that the BD pair is unlike AA and CC as it is neutral in gravitational terms and has a negative inertial mass.

As with the AB combination, it would manifest itself as a gravitational dipole, but this time it would be stable in-situ rather than accelerating to light speed.

On the basis that the binary pairs are stable in-situ, we refer to them as "cold".

4 Light Combinations (Hot)

As we saw with Model AB, it is possible for particles with opposite inertial masses to combine and accelerate to the speed of light. This time there are 4 cases to consider:

Binary Pair	Gravitational Mass m_g	Inertial Mass m_i
AB	0	0
BC	-2	0
CD	0	0
DA	+2	0

Clearly they are all similar in the sense that the combined inertial mass is zero.

We can think of AB and CD being matter / antimatter equivalents of each other. Likewise with BC and DA.

The big difference comes when we look at the combined gravitational mass, where BA and DA have double-magnitude masses with opposite signs. We would therefore expect their behaviour to be different when interacting with other particles.

Comversely, whereas the individual components of AB and CD have the same response to an external field, we find that the components of BC and DA have opposite responses. In particular, this means that BC and DA would be unstable and hence dissociate in the presence of a strong field.

On the basis that all of the light combinations accelerate to light speed, we refer to them as "hot".

4 Symmetric Triples (Warm or Cold)

Whereas Model AB gave us the BAB triple, Model ABCD gives us another 3 cases to consider:

Symmetric Triple	Gravitational Mass m_g	Inertial Mass m_i	Rating
BAB	-1	-1	Warm
DCD	+1	-1	Warm
BDB	-1	-3	Cold

DBD	+1	-3	Cold

Again we can think of BAB and DCD as matter / antimatter equivalents.

Given that the central A is repelled by the 2 Bs in the BAB triple, it is possible to replace it with a central D particle that still attracts the 2 Bs but is also attracted to them itself.

This gives rise to the BDB triple and its antimatter equivalent DBD. In these cases the components add up to a triple-magnitude inertial mass overall.

On the basis that all of the symmetric triples are stable in-situ, we might refer to them as "cold". However, there is a scenario where BAB and DCD will decompose and release "hot" particles as we will see next. Hence we refer to them as "warm".

Simulation of Electron-Positron Annihilation

At this point, it is tempting to compare our generalised version of gravity with electromagnetism. Although we now have candidates for electrons and positrons (B and D respectively) on the grounds that likes repel and opposites attract, what happens when they encounter each other?

In the real world, we get a phenomenon known as Electron-Positron Annihilation, whereas in our model it seems that B and D simply orbit each other to form a BD pair.

If we look a little closer though, we find that electrons and positrons do indeed start to orbit each other in a configuration known as Positronium. In fact they never appear to get closer than the size of the atomic ground state in neutral hydrogen (56,000 times the diameter of a proton), yet after 125 picoseconds they emit 2 gamma ray photons (or 3 photons after 142 nanoseconds) totalling the sum of their mass energies according to Einstein's formula $E = mc^2$.

Whilst we don't see this behaviour with just B and D, we can see something similar if we look at the interaction of BAB with DCD:

BAB + DCD → AB + CD + BD

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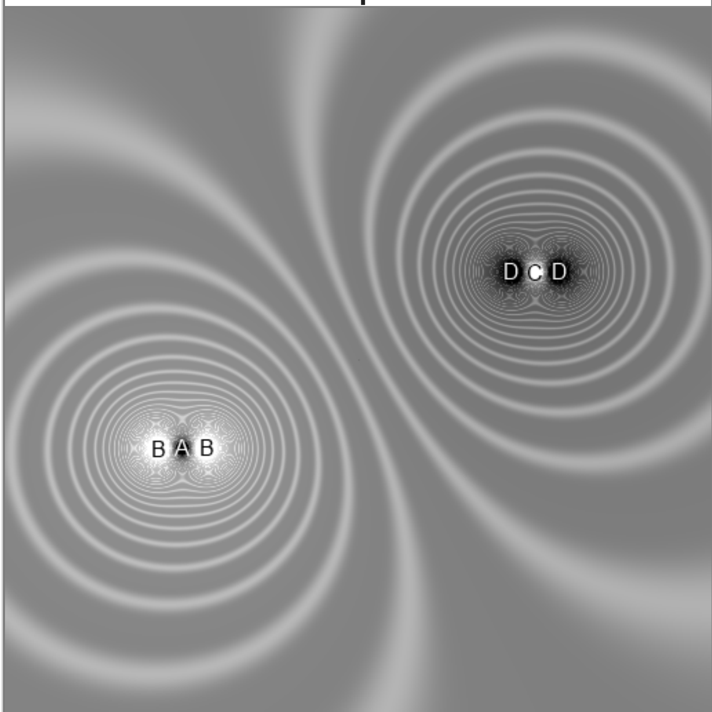
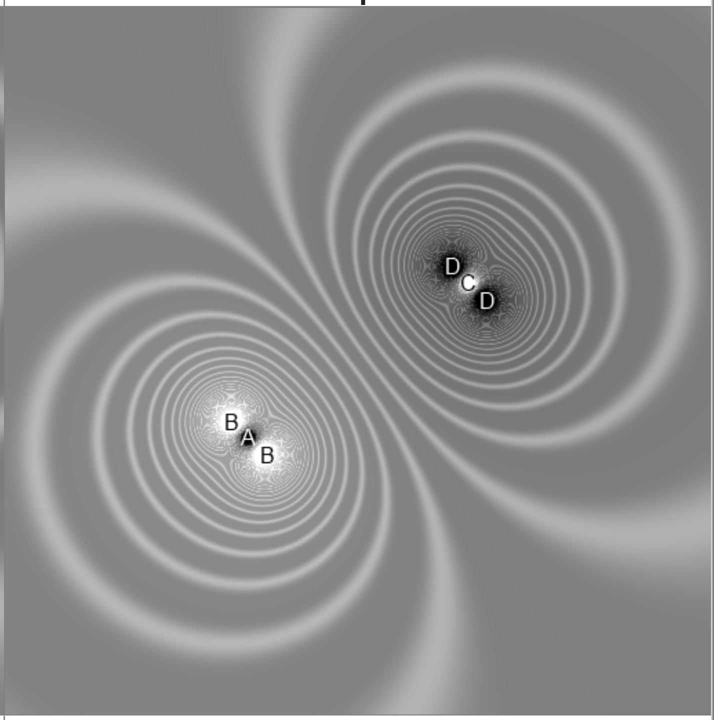
<tr><td>
</td><td>
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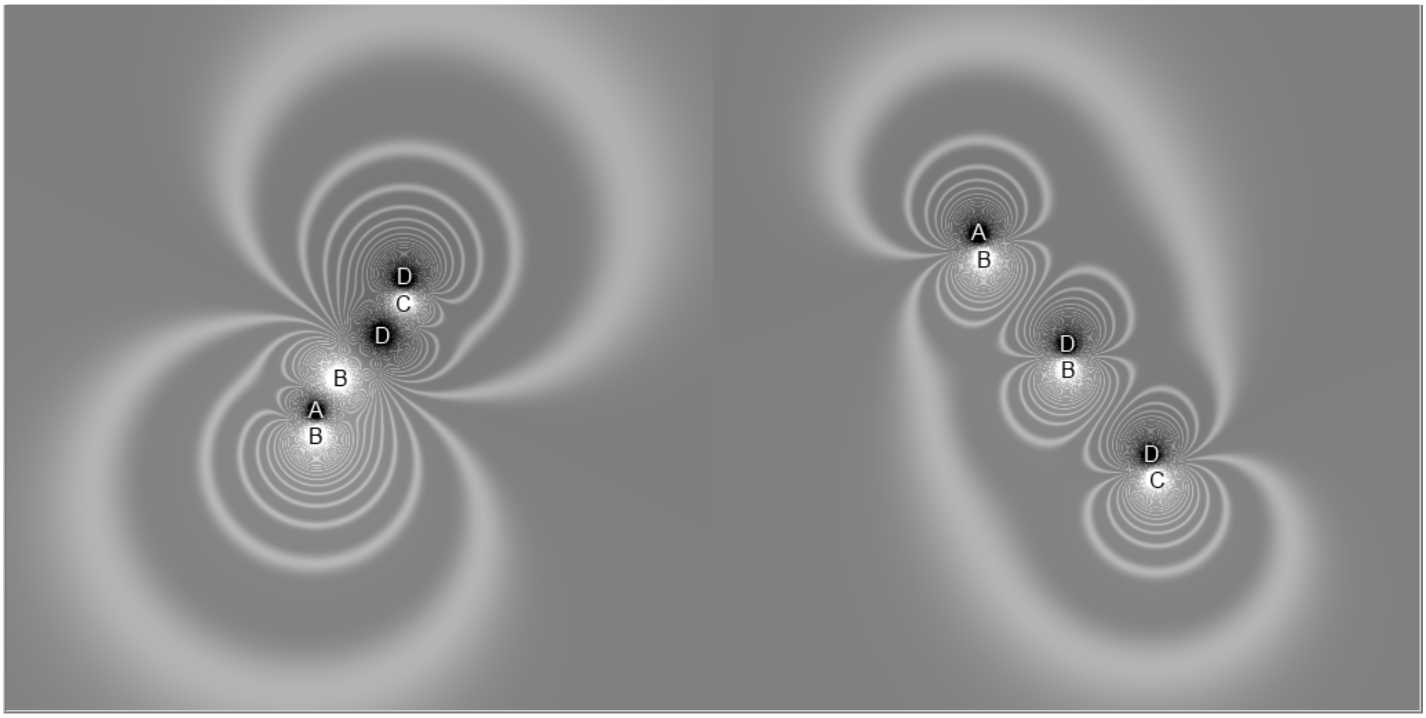

Effectively, the reaction generates the 2 light combinations AB and CD, which start to accelerate in opposite directions because the A and C repel each other. It also generates the neutral BD pair.

If BAB and DCD are analogous to the electron and positron and AB and CD are similar to photons, then what do we make of BD?

This leads to the second prediction from our unified gravitational model. In the case of electron-positron annihilation, we expect a third (neutral) particle to be generated by the reaction. In contrast to the photons which accelerate to the speed of light, the neutral particle remains in-situ in the original frame of reference.

In particular, this prediction is consistent with the analysis from Don Hotson, based on conservation of angular momentum. In his 3rd paper, he refers to the electron-positron pair or "epo" as part of the quantum vacuum. The epo is equivalent to the neutral composite BD particle in our model.

We might further speculate that singletons or neutral pairs are undetectable with current technology and hence part of the quantum vacuum. With this line of reasoning, only charged composites, heavy composites or light combinations would be detectable.

Summary

Again we can simulate a Model ABCD universe with a computer. There is certainly a lot more going on compared to Model AB. After extensive analysis we come to much the same conclusion though, i.e. that it's too simple to simulate everything that goes on in the real universe.

The sticking point this time surrounds particles with differing masses. Although we might take the approach that heavier particles (such as the proton and neutron) are composite particles made from large numbers of smaller ones (such as the electron and positron), we have no way of explaining why the proton and neutron in particular are stable, while pretty much everything else isn't.

At this point, it might be tempting to go looking for the meaning of life in the bottom of a beer glass. What we need is another bit of inspiration...