OUR UNIVERSE

Part 3

In the previous part, I talked about the constituent particles of matter, some of the hierarchy, and how they interact through the four forces of nature. Here I bring that together through the various forms of energy, thinking of particles as waves, and the process all around us of creating matter that led to the evolution of the Universe.

The energy of mass, in units of Joules, is the mass in kilograms times the square of the speed of light in meters per second (Einstein's famous equation). Then there is kinetic energy, the energy from motion of matter, simply half the mass times the square of the speed. The expansion of the Universe, due to the moving apart of all the matter within it, shows that it also has a great deal of kinetic energy. Another form of energy is from photons. That is light, heat and radio waves; these can be thought of as a wave train of electrostatic and magnetic oscillating fields travelling through space. The energy is proportional to the frequency of the wave. The scaling constant is Planck's constant , a fundamental constant of nature which I will describe later. Photons are naturally emitted by all matter bodies according to their surface temperature. The Sun is an example at nearly 6000°C, with peak brightness in optical wavelengths; while our surroundings and we ourselves have peak emission brightness in infrared wavelengths, as seen in a thermal camera.

Ordinary matter particles can be thought of as stationary waves, like standing waves of a vibrating string of a musical instrument. With this analogy, the higher the pitch then the shorter the wavelength. The fixed ends cannot move up and down and, because of that, must have whole numbers of half wavelength between them. This constraint sets the waves into a series of harmonics. For particles, the range of energies is confined by their own mass energy, and leads to quantum energy states from low to high, all separated like the rungs of a ladder (the different harmonics). Each harmonic has an energy associated, making them all distinct. Again the scaling of wavelength to energy is by the speed of light and Planck's constant.

The orange colour of a traditional streetlight is due to emission of light of a specific frequency (that is energy) caused by an electron jumping between two energy levels in the sodium atom, releasing the energy difference as a photon of light. It is the same feature in the Sun, which is darker in that particular colour, showing that there is sodium in the Sun's atmosphere, absorbing the light from the surface below and re-emitting it in all directions.

The energies described so far are all positive, but the binding forces of nature are all negative energy, including gravity. Standing on the Earth we are at the lowest energy point without going underground ; that is why we don't go flying off! When we throw a ball into the air, we need energy to do so. But, as gravity reduces with increasing distance, at infinite range from the Earth its gravitational force is zero, and so its gravitational energy is zero. This makes gravitational energy, at any distance, negative (as its maximum value is zero). Recall that in the helium atom, consisting of protons and neutrons, they have lower energy in combined form than the sum of its constituent parts. When the hydrogen protons fuse together to form helium in the centre of the Sun they become lighter in weight, in having lower combined mass energy, and they release the difference as photon energy, which powers the Sun.

A satellite orbits the Earth in the same way as a planet orbits the Sun, by balancing the force of gravity between them (negative energy) and orbiting with the kinetic energy of motion in a fixed relationship. It is just like a swinging pendulum, where at its maximum height it has maximum gravitational energy (height above the ground) and no motion, so no kinetic energy. Whereas at the bottom of its swing it has its minimum gravitational energy (height above ground) and maximum kinetic energy from its motion. At all times the sum of the two is constant and is simply oscillating from one to the other. Orbits of planets are elliptical, with the Sun at one focus of the ellipse, so in their path they vary in distance from the Sun and accordingly vary their speed in compensation to maintain the same total energy at all times.

The expansion of the Universe is the ingredient needed to perform its energy balancing act. The kinetic energy from the expansion is exactly that required, together with all its mass energy and other positive energies, to balance the negative gravitational energy of all its mass: a state of perfect balance that has been maintained from the beginning, and always will be. That is why it has never collapsed due to its gravity and that is why the expansion rate is what it is. It makes the overall energy of the Universe zero! Then we don't have to ask where the energy came from to start it. Every point in the Universe is expanding from every other. Imagine a rubber balloon being blown up, with dots all over its surface representing galaxies, each one moving away from each other. The further ones move more rapidly because there is more rubber (i.e. space) between them to expand. So the apparent expansion is proportional to the distance from the observer on the surface, wherever one is. There is no preferred point; expansion is to everywhere from everywhere.

Mass bends the direction of light passing through its gravitational field. If we went off round the Universe and it wasn't expanding, eventually we would come back to where we started, as light will be bent round in a circle by the mass of the Universe. This is what happens in a black hole, such as in a collapsed massive star, where gravity is so strong that light cannot escape. But because the Universe is expanding at exactly the right rate, we would never get round to come back, as it had expanded in the meantime. So rather than the Universe looking curved back on itself like a ball, it looks completely flat: a consequence of its overall energy being zero.

And now let us go back to the very small for the process of creation! What brings everything together is uncertainty! For example, in measuring the speed of anything, such as light, it is simply distance divided by the time to travel the distance. If the measuring time is short then we become less certain of the speed. Another analogy: if we have a video sequence stored digitally as a file on a computer, then for the same file size (same amount of data) we can have a much higher spatial resolution single frame. That will give us a picture in much greater detail, but give us no information as to what happened in time either side. While in the digital video we have the time sequence, but with much lower spatial content, so there is more uncertainty as to what was where at a given moment. Nature is just the same!

Planck's constant, mentioned above, is a fundamental constant of nature (like the speed of light) and has units of energy times time, or momentum times distance (the same) and is a very small number. It scales stepped properties (like wavelength, frequency, time) to stepped units of energy in all particle physics.

The uncertainty in measuring the energy of anything relates to the length of time it was measured over. The shorter the time, the more uncertain is the energy, and vice versa. The

two multiplied together are a scaling of Planck's constant. Similarly for measurement of momentum (mass times speed) at a particular spatial position, the same relative uncertainties apply. So the energy or momentum for any particle is never zero. The minimum of the two multiplied together is given by Planck's constant, which is never zero; so neither component can be zero. So neither the energy value nor time value for the vacuum of space can ever be zero. The energy of the vacuum of space is not zero! It is a virtual cauldron of the particle world!

Thus particles and anti-particles (an antiparticle is the same as a particle, but with opposite electric charge) can be created out of the vacuum, momentarily. But once the time is up specified by Planck's constant and the total mass energy of the created particle antiparticle pair plus a little to keep them apart, that total energy has to be provided from somewhere, otherwise they must mutually annihilate. If sufficient mass energy is available from elsewhere, such as from particle collisions or interaction from very high energy photons. Then the particle and antiparticle pair will materialise into reality, permanently.

This is not magic, it's happening all the time all around us, instantly! But without a source of energy the particle- antiparticle pairs annihilate back into the vacuum. Right at the beginning of the Universe, such particles and antiparticles were created out of the vacuum and the Universe was NOT old enough for them to annihilate. So they were living on energy from borrowed time from nothing. The more mass energy needed, the less borrowed time in proportion (remember the two multiplied together are a scaling of Planck's constant).

But right at the beginning it wasn't only expansion, but inflation, faster than the speed of light, that occurred momentarily. In that moment the pairs of particles and antiparticles just created couldn't get back together again to annihilate, as space is ripped apart faster than light. As they were separated, their mutual attraction broke, like a rubber band breaking (the two particles representing the ends of the band). This process creates two more particle pairs from the freed energy (the rubber band breaking in to two rubber bands, thus creating four ends). This is a cloning process and it continues like a manufacturing production line, so filling the space with created, cloned particles. The energy required slowed down the inflation to ordinary expansion speed, finally managing to balance it all to overall zero energy, as described above.

In the first few micro-seconds of the Universe, up to a minute, it went through a series of phases of high energy particles being created, then annihilated and decaying to more stable lighter weight ones. Each phase change released energy for the next particle production process, and slowing down the expansion to maintain, against gravity, an overall energy of zero. As the Universe expanded, the energy density dropped, so high mass energy particles could no longer be created and they decayed, leading to only longer lasting ones of lower energy.

The analogy of each phase change is like that of water. At 100°C water needs energy to turn into steam at the same temperature, whereas at 0°C water needs to have energy removed from it in order to turn it to ice at the same temperature. Ice crystals have only a few angles of symmetry compared with water, which is the same in all directions; and so this cooling to ice is a loss of symmetry with the release of energy. Similarly, in the early universe phase changes produced loss of symmetry (more complex laws and particles and forces were thus created) from the energy released. This all happened very rapidly for a few seconds, whereupon

ordinary protons and neutrons and electrons of hydrogen and helium were the final outcome. 300,000 years later through the expansion of the Universe its temperature was cool enough for the electrons to combine with the hydrogen atoms to produce the final release of energy in the form of heat and light. This is still around everywhere as bright as full moonlight but through the expansion of the Universe in the last 13 billion years has been stretched down to microwave wavelengths.

I have described the dual concepts of waves of energy matter, which do not have a particular location or path when moving, and of particles, which one thinks of as uniquely located and with direction when in motion. Amazingly this uncertain wave behaviour is real for all matter, and is only resolved into a particle state by our own observation. This can be demonstrated in the laboratory and leads to the anthropic principle, which I will discuss further in the final part, together with the scale of everything. This explains how the Universe is as it is precisely because we are here to see it. Also how we **may** or **may not** determine our own history and our own future in our glorious Universe!

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