A FORMAL TECHNICAL TEXT

Neutrino astronomy. Neutrinos (or “little neutral ones”) are tiny, almost massless elementary particles that were postulated by Pauli in 1930, named by Enrico Fermi in 1934, but not detected until 1956, when they were finally observed in a nuclear reactor by US physicists Frederick Reines and Clyde Cowan. The long delay between hypothesis and observation arose because the interaction between neutrinos and matter is so puny that a neutrino can pass through a light-year thickness of lead before interacting with an atom. So weak is the neutrino–matter interaction, in fact, that we are blissfully unaware of the vast numbers of neutrinos that pass unfelt through our bodies every second, day and night. Cosmic neutrinos are produced in stars, supernovae, AGN, gamma-ray bursts, cosmic-ray interactions in the atmosphere, and in the Big Bang, and they exist over a vast range of energies and fluxes. Although their feeble interactions make them hard to detect, when they are detected it means that many will have come from electromagnetically inaccessible regions of the Universe, making them highly informative messengers. The first ever neutrinos detected from outside the solar system were from the supernova SN1987A in the Large Magellanic Cloud, an observation that really started high-energy neutrino astronomy.ursts of neutrinos were detected several hours before the arrival of the first photons; arriving from the direction of the southern skies, the neutrinos had to traverse the body of the Earth before entering the detectors of the Kamiokande neutrino experiment in Japan and the Irvine–Michigan–Brookhaven (IMB) experiment in the USA, both located in the northern hemisphere. Each experiment saw a near-simultaneous, twelve-second-long burst of neutrinos. What caused the delay between the observed neutrino and photon signals? When the core of a massive star collapses, a massive amount of gravitational energy is released, which is mostly carried away by neutrinos. These stream out from the collapsing core at almost the speed of light and do not interact significantly with the rest of the star. The photons, on the other hand, interact strongly with the expanding cloud of ejecta from the explosion and scatter multiple times before finally being released into space, thus accounting for the time delay. Neutrinos exist in three “flavours”: electron, muon, and tau neutrinos, which interact with their respective paired elementary particles. A neutrino travelling through space morphs between the three flavours, a property known as neutrino oscillation. A neutrino emitted with, say, an electron flavour can, when observed later, be seen as a tau or a muon neutrino. An important source of astrophysical neutrinos is the series of fusion reactions that converts hydrogen into helium and powers the stars. When four protons come together to fuse into helium in a star, two of them must convert into neutrons via the nuclear beta-decay process. This interaction also releases positrons and electron neutrinos. Each second, the Sun produces over 10^39 neutrinos in its core, which pass through the stellar surface in about a second before flying off into space. The solar neutrino flux is so large that even on Earth, 150 million kilometres away, 100 billion neutrinos zip through your thumbnail every second. From 1964 onwards, US astrophysicist John Bahcall developed the standard solar model, which predicts the solar neutrino flux on the basis of the conditions and known fusion reactions in stars. (an excerpt from Geoff Cottrell’s Observational astronomy’’)

LITERARY-TECHNICAL TEXT

Look, it can exist in the Autoverse" ... the obvious response to that will be: "Yes, it can exist—if you put it there by hand—but that doesn't mean it's ever likely to have formed." If we can demonstrate a range of starting conditions that lead to planetary systems with suitable worlds, that will be one less element of uncertainty to be used against us."

Durham had eventually agreed, so she'd taken an off-the-shelf planetary-system modeling program—irreverently titled The Laplacian Casino—and adapted it to Autoverse chemistry and physics; not the deep physics of the Autoverse cellular automaton, but the macroscopic consequences of those rules. Mostly, that came down to specifying the properties of various Autoverse molecules: bond energies, melting and boiling points versus pressure, and so on. Aqua was not just water by another name, yellow atoms were not identical to nitrogen—and although some chemical reactions could be translated as if there was a one-to-one correspondence, in the giant fractionating still of a protostellar nebula subtle differences in relative densities and volatilities could have profound effects on the final composition of each of the planets. There were also some fundamental differences. Since the Autoverse had no nuclear forces, the sun would be heated solely by gravitational energy—the velocity its molecules acquired as the diffuse primordial gas cloud fell in on itself. In the real universe, stars unable to ignite fusion reactions ended up as cold, short-lived brown dwarfs—but under Autoverse physics, gravitational heating could power a large enough star for billions of years. (Units of space and time were not strictly translatable—but everybody but the purists did it. If a red atom's width was taken to be that of hydrogen, and one grid-spacing per clock-tick was taken as the speed of light, a more or less sensible correspondence emerged.) Similarly, although Planet Lambert would lack internal heating from radioisotope decay, its own gravitational heat of formation would be great enough to drive tectonic activity for almost as long as the sun shone.

Without nuclear fusion to synthesize the elements, their origin remained a mystery, and a convenient gas cloud with traces of all thirty-two—and the right mass and rotational velocity—had to be taken for granted. Maria would have liked to have explored the cloud's possible origins, but she knew the project would never be finished if she kept lobbying Durham to expand the terms of reference. The point was to explore the potential diversity of Autoverse life, not to invent an entire cosmology.

Gravity in the Autoverse came as close as real-world gravity to the classical, Newtonian inverse-square law for the range of conditions that mattered, so all the usual real-world orbital dynamics applied. At extreme densities, the cellular automaton's discrete nature would cause it to deviate wildly from Newton—and Einstein, and Chu—but Maria had no intention of peppering her universe with black holes, or other exotica. (an excerpt from Greg Egan’s book *Permutation City*)