The Economist

Astrobiology

Bolts from the blue

The history of life in the universe may have been governed by the frequency of giant stellar explosions

Oct 18th 2014 | From the print edition

WHERE are they? Aliens, that is. Why is there no sign of intelligent life in the universe anywhere other than on Earth? That question has puzzled inquiring minds for centuries, and has become more pressing over the past few years, as the discovery of planets going around stars other than the sun suggests the Milky Way (Earth's home galaxy) harbours billions of worlds suitable for life, in that they are orbiting within a habitable zone warm enough to keep water liquid, but cool enough not to boil it.

There are many possible answers, of course. The origin of life may be hard. The evolution of intelligence may be hard. Intelligent life, having evolved, may find it impossible to devise technology to travel from star to star, or may not think the effort worth it.

But there is another possibility. In a paper published on arXiv (http://arxiv.org/abs/1409.2506) , an online repository, two astronomers, Tsvi Piran of the Hebrew University of Jerusalem and Raul Jimenez of the University of Barcelona, argue that some regions of the galaxy are less friendly to life than others. Moreover, the friendly areas may have been smaller in the past than they are now. If that is true, then it may be the case that complex life on Earth is just about as ancient as it is possible for complex life to be. And, since complexity necessarily precedes intelligence, that might mean human beings really are the first intelligent life forms to evolve in the Milky Way.

Gamma minus

Dr Piran and Dr Jimenez are interested in gamma-ray bursts (GRBs), the most energetic phenomena yet discovered in the universe. No one is certain what causes them, but the leading theories are a hypernova—the sudden collapse of a massive star to form a black hole—or a collision between two neutron stars, the ultra-dense remnants of supernovas (slightly less massive collapsed stars). What is not in doubt is their prodigious power: a typical GRB generates as much energy in a few seconds as a star will in its entire multi-billion-year lifetime. That would be bad news for any life-bearing planet which was too close.

Fortunately, GRBs are rare. Satellites detect an average of one a day but, given that they are visible from (quite literally) halfway across the universe, with all its billions of galaxies, that is a reassuringly low rate. These observations do, though, give astronomers a lot of data to crunch, and these Dr Piran and Dr Jimenez have made use of. By combining findings on how common GRBs are, how bright they can be, and where and in what sorts of galaxies they occur, the two researchers have built a model which attempts to predict the risk that a given planet, located somewhere in a given galaxy, will find itself in the line of fire.

The idea that a nearby GRB (nearby, in this context, means within about 10,000 light-years) would wreck the biosphere of an Earthlike planet was proposed in 1999 by James Annis of Fermilab, in Illinois. First, the blast of radiation would instantly kill most living organisms on or near the surface—not just those facing the blast but also, via secondary showers of charged particles and re-emitted gamma rays, those on the hemisphere facing away from it. Second, the gamma rays would also stir up chemical reactions that create ozone-killing molecules sufficiently powerful to destroy more than 90% of an Earthlike planet's ozone layer, and keep it destroyed for several years. This would let in intense ultraviolet light from the planet's parent star, which would blitz any complex biological molecules it hit. Anything that survived the initial blast would thus be subjected to years of serious sunburn.

The Earthlike planet of most interest to human beings is, of course, Earth itself. Mankind's home is 4.6 billion years old, and Dr Piran's and Dr Jimenez's model suggests there is almost a 90% chance that it has been hit by at least one GRB of this power in that period. For the first half of Earth's existence, only the direct impact would have mattered, since there was no ozone layer to annihilate (the simple bacteria which existed at this time were either adapted to UV, or lived underground or underwater and were thus immune to its effects). But once photosynthesis started (about 2.3 billion years ago), oxygen—and therefore ozone, the triatomic form of that element—began to accumulate, and living things came out of hiding and got used to living under its protection. From then on, a nearby GRB would certainly have caused a mass extinction.

Any extinction that happened before about 540m years ago, when shelly animals appeared and fossils became commonplace, would probably be invisible in the geological record. But since then there have been five—one of which, that at the end of the Ordovician period, has no obvious explanation. Perhaps not coincidentally, Dr Piran's and Dr Jimenez's model suggests there is a 50% chance Earth has been struck by a GRB in the past 500m years.

ET cetera

The odds Dr Piran and Dr Jimenez have found for a knock-back of life on Earth sound threatening enough, but they still think the planet has had it lucky. The solar system orbits about 24,000 light-years from the Milky Way's centre. Nearer in, the density of stars—and therefore of GRBs—is greater. About a quarter of the Milky Way's stars (and therefore planets) are so close to the core that the chance of their being hit by a catastrophic GRB at least once every billion years is greater than 95%, and fully half are close enough in that there is a 80% chance per billion years of their suffering. Moreover, that calculation is based on the Milky Way's current composition. In the past, things would have been worse.

In astrospeak, the Milky Way is a metal-rich galaxy. With a fine disregard for their chemist brethren, astronomers refer any element except hydrogen and helium as a metal. The distinction is that (a tiny amount of lithium aside) hydrogen and helium were the only elements created in the Big Bang. The others have been formed by nuclear fusion inside stars or, in the case of the heaviest, in supernova explosions that have destroyed stars. This means they have become more abundant as the universe has aged.

The pattern of GRBs shows that they have got rarer over the course of time and suggests that this is, in particular, associated with the accumulation of metals. In galaxies of the same age, more metallic ones are less likely to give rise to a GRB. This makes sense, at least if the stellar collapse model is the right one. Nuclear physics predicts that metal-rich stars are not able to undergo the sort of spectacular collapse necessary to produce a burst. Were it not for the Milky Way's high metallicity, Dr Piran and Dr Jimenez reckon, GRBs would be common enough that a planet almost anywhere in the galaxy would have suffered from at least one in the past billion years. They estimate that even now only 10% of the universe's galaxies would host sufficiently few GRBs to give the evolution of complex life a fair run. Presumably, in its less-metallic past, that would have been true of the Milky Way as well.

Whether the constant pressing of the evolutionary reset button suggested by the calculation Dr Piran and Dr Jimenez have made really is the explanation for humanity's lack of contact with alien civilisations is, of course, a matter of speculation. But their work does indicate that the older the universe gets, the friendlier it becomes towards life. They reckon that, before about 5 billion years ago, GRBs were so frequent that life would have struggled to establish a foothold anywhere in the cosmos. If astronomers ever do discover life on another planet, then, it is unlikely to be much older than life on Earth itself.

From the print edition: Science and technology