A Sense of Wonder

I am a child of the space age. I grew up reading Eagle comic, which featured the exploits of space-travelling "pilot of the future" Dan Dare, together with detailed technical illustrations of real rockets. I was eleven the year Sputnik 1 went into orbit, by which time I had already moved on to reading realistic science fiction (and science fact) from Arthur C. Clarke, Isaac Asimov, and the magazine Astounding, which later metamorphosised into Analog. It was, perhaps, inevitable that I would follow a career path into astronomy, and then into writing about astronomy, sharing my sense of wonder at the Universe unfolding before the gaze of ever more sophisticated observing technology, much of it being launched into space, some of it by ESA. Slightly less predictably, I extended this sharing into fiction, even placing stories in Analog magazine, one of my proudest achievements.

The personal rewards for this are twofold. Dr Johnson is reported as saying that "no man but a blockhead ever wrote except for money", and it is certainly true that, while money might not always be the primary motivation for an evangelical space enthusiast such as myself, in the words of the Lorelei Lee character from the movie *Gentlemen Prefer Blondes*, "my goodness, doesn't it help". But the greater satisfaction comes from introducing a new generation to the modern equivalent of the things that excited and inspired me in the 1950s and 1960s. To my (pleasant) surprise, just as I was inspired by Clarke, Asimov and the rest, over the years I have heard from many people, some of whom have gone on to far more significant careers in astronomy and space research than me, that they were inspired to take this career path by my writings. And that is why I welcomed the opportunity to contribute to this beautiful book. To be sure, it is full of stunning pictures, and you can enjoy them without bothering too much about their origins. But even a moment's thought brings home with full force the realisation of the astonishing achievement they represent.

Take something as simple as an astronaut's glove. It is just a glove. But it has been worn by an astronaut. Human beings really do travel into space wearing gloves like this. They are science fact, not science fiction. I have even met an astronaut, Rusty Schweickart. But he isn't famous, because he wasn't the first to do anything impressive to outsiders, nothing went wrong on his mission, and he was "only" in Earth orbit. Only! Sixty years ago, this was the stuff of Dan Dare. Now, it is just routine. Today, if a rocket launch fails, it is news; fifty years ago, it was news if a rocket launch succeeded.

Or take something as seemingly complicated as the age of the Universe. Fifty years ago, the best that astronomers could say was that the Big Bang in which the Universe as we know it was born occurred some time between 10 and 20 billion years ago. It was, in fact, an astonishing achievement to be able to say even this with confidence. But now, thanks to unmanned space observatories such as ESA's Planck satellite, we can confidently state that the age of the Universe is 13.8 billion years. Not 13.7 billion years, not 13.9 billion years, but 13.8 billion years. Impressive, you may say (or perhaps you are not impressed?), but not very useful in everyday life. Well, look at some of the practical achievements that we take so much for granted that we do not usually stop to think about what they really mean, and try to rekindle your sense of wonder.

Around the time I was being introduced to Dan Dare, I used to listen to the BBC's live radio commentary on Test cricket from Australia, snuggled up in bed because of the time difference, when my parents thought I was asleep. This commentary made its way from the other side of the world via a series of telephone cables before being broadcast over the airwaves in the UK. At its best, the words could be heard reasonably clearly, often coming and going like waves on the beach; at its worst, the commentary was completely lost in noise, and the frustrated listener might miss key moments in the match. But somehow these inconveniences only served to emphasise how amazing it was that I could

be listening to what was going on in Australia at the very moment it was happening. The imperfections of the broadcast only served to remind me that Australia was just about as far from home as it was possible to get on Planet Earth. Now, I can watch the cricket from Australia live in high definition and colour on widescreen TV, and get annoyed if there is a momentary pixellation of the image. I expect the pictures to be as perfect as the ones from a studio in London. Then I remind myself how things used to be before the space age.

The example of GPS -- Global Positioning by Satellite -- and its offspring SatNav is almost too obvious to mention as a wonder of the space age, except that there is a largely unappreciated cause to wonder at this feature of modern life. The systems used in working out your position on the surface of the Earth (or the course of an airliner through the sky) are so accurate, and the satellites used in those measurements move so fast and so high, that they have to allow for the distortions in time and space explained by Albert Einstein's special and general theories of relativity. It is less than a hundred years since Einstein came up with the general theory (in 1915; the special theory dates from 1905), which is regarded as one of the most difficult and esoteric theories in science; and yet, thanks to space technology, it has everyday applications in a device you probably have in your pocket now, a smartphone.

And the space age has also opened our eyes to wonders of the Universe that may seem as esoteric to us now as Einstein's ideas did ninety years ago, but may have implications for the 22nd century that we cannot imagine now any more than Einstein imagined GPS.

There are, in my view, two equally mind-blowing candidates for the most amazing scientific discovery of the space age. The first I have already mentioned -- the measurement of the age of the Universe, the time since the Big Bang, with exquisite precision. This is, I admit, a rather exotic piece of

information, no matter how impressive, with no obvious human relevance. But the second candidate is much closer to home, both literally and figuratively.

One of the great questions, not just of science but of philosophy and religion, is, are we alone in the Universe? Life like us requires a planet like the Earth to live on, and until the 1990s the only planets we knew were those of our Solar System, and the only one like the Earth was -- the Earth. There are now several thousand known “exoplanets” -- planets which orbit stars other than the Sun -- and a statistical analysis of these discoveries makes it possible to calculate the probability of finding a planet like the Earth orbiting its parent star in the so-called life zone, the region where liquid water, a pre-requisite for life as we know it, can exist. It turns out that about one in five Sun-like stars should, according to this analysis, have an Earth-like planet. And there are billions of Sun-like stars in our Milky Way Galaxy. The most dramatic way of interpreting the statistics is that they imply that the nearest Earth-like planet to our Solar System is orbiting a Sun-like star within 12 light years of us. By astronomical standards, this is almost next door; the nearest star to our Sun is just over 4 light years away. A star like the Sun only 12 light years away would be visible to the naked eye. Although there is at present no way to tell which of our neighbouring stars might be the one that has a planet suitable for life as we know it, this means that if you look at the night sky from a dark location far away from city lights, at least one of those twinkling specks of light on the sky is probably home to a planet like ours. If that doesn’t blow your mind, nothing will.

The next generation of scientific satellites, notably ESA’s GAIA mission, should be able to identify Earth-sized planets orbiting nearby stars; the next step will be to test whether they are life-bearing planets, that close to us, by analysing the spectrum of light from their atmospheres. This should be achievable within twenty years. Finding intelligent life, though, is likely to be a lot harder. For all the success of missions like Gaia, the Universe is still a big and largely empty space.

Many of the images presented here also reinforce the message that was brought home by the first astronauts to orbit the Moon, with their photograph of the “blue marble” of the Earth, streaked with white clouds, rising above the rim of the dry, grey deserted Moon. This Earthrise image, which emphasised the fragility and isolation of our home in space, is credited with providing a major impetus for the Green movement in the 1970s, encouraging the idea that we need to husband our resources and care for the planet on a global scale. The perception of the Earth changed for millions of people who had never themselves left the planet. The sense of isolation and emptiness conveyed in many of the images here strikes the same chord. Almost paradoxically, although the images from space are themselves both figuratively and literally cold, and almost empty, they trigger something in us which stimulates the imagination and enriches us, for want of a better word, spiritually. Many astronauts report such a transcendental experience; now, we can catch a glimpse of what they have seen, and share that experience in some small way.

This is, of course, linked to the scientific imagination required to envisage space travel as a means of exploring the Universe and understanding better the planet on which we live. I have already mentioned the Gaia satellite which will search for stars which may be orbited by planets like the Earth. What I did not mention is that Gaia will map the locations of a billion stars in our Milky Way Galaxy -- roughly one per cent of the entire stellar population of the Milky Way. As Jos de Bruijne, ESA Gaia Deputy Project Scientist, has explained, “if the final catalogue with just the summary of all data accumulated by Gaia were printed and all volumes were nicely aligned in my bookshelf, the row of 53,542 volumes would extend 1.3 km”. The leap of the imagination required to contemplate building a satellite capable of getting all this data is matched by the leap of the imagination required to program computers to handle it all, finding patterns and correlations which will surely lead to new insights into the structure, dynamics, and history of the Milky Way.

This kind of analysis depends on simulations of reality -- the “history” of the Milky Way will be interpreted by measuring the present day positions and motion of the stars, then winding the clock backwards in a computer. Simulations are at the heart of modern science, and it is sometimes hard to know where the simulation ends and reality begins. This is famously so in quantum physics, where objects are sometimes described in terms of waves, and sometimes in terms of particles, but are “in reality” nothing like anything we experience in everyday life. In fact, almost all of science is a simulation. We talk about perfectly spherical balls rolling about on frictionless tables to explain Newton’s laws of mechanics, and we work out the orbit of the Earth around the Sun by assuming that both the Sun and Earth are “point masses”, not spread out objects. A physicist takes all this for granted; but I was set thinking about the nature of simulations by images of the training modules for spacecraft such as Mir (nr. 63 url) and the ISS (nr. 56 url), perfect in every way (except for zero gravity!). By the time an astronaut gets into space, he or she is literally able to find their way around the actual spacecraft blindfold.

Another kind of simulation concerns the environment on board a manned spacecraft or the space station. There, conditions similar to those on the surface of the Earth are simulated in order to keep people alive. And life support systems for much longer flights, eventually, perhaps, to Mars, are being developed at the Melissa Pilot Plant in Barcelona.

But the most impressive images, for a child of the space age such as me, are those of the spacecrafts, themselves. This, after all, is what makes everything else possible, including measurements of the age of the Universe and the history of the Milky Way Galaxy, and one day, just maybe, journeys into space to Mars and beyond. For the more immediate future, one particular mission stands out. This is BepiColombo, ESA’s first mission to the planet Mercury, the innermost planet of our Solar System. Mercury is a small planet with very high density, and a very hot surface, scoured by particles from the Sun (the solar wind).

Understanding its properties will help scientists to understand how it formed, and provide insights into the evolution of the Solar System. But first, the spaceprobe has to get there.

The BepiColombo mission highlights the sheer complexity of modern space projects. In August 2015 a single launch vehicle will carry both a Mercury Planetary Orbiter (MPO); and a Mercury Magnetospheric Orbiter (MMO) into space. BepiColombo will then fly a looping journey past the inner planets of the Solar System (Earth, Venus and Mercury) using their gravity as well as the thrust from solar-electric propulsion (SEP, popularly known as “ion drive”) to reach its destination. During the voyage to Mercury, the two orbiters and a transfer module (the main “engine”), made up from electric propulsion and traditional chemical rocket units, will form one single spacecraft. In 2024, as BepiColombo nears Mercury, the transfer module will separate and the joined spacecraft will use rocket engines to bring it into a polar orbit around the planet. The two components will then separate, with the MMO staying in a relatively high orbit and the MPO dropping into a lower orbit. BepiColombo will make a complete map of Mercury, chart the planet's mineralogy, and find out if the interior of the planet is molten. It will also investigate the extent and origin of Mercury’s magnetic field.

To put this in perspective, as recently as 1957 one of the greatest achievements of human technology was to put a simple satellite, Sputnik 1, in orbit a few hundred kilometres above the surface of the Earth, carrying nothing more sophisticated than a one-watt radio transmitter emitting a series of beeps. Sputnik 1 was a sphere just 58 cm in diameter and weighing just over 83 kilos. The body of BepiColombo measures 2.4 x 2.2 x 1.7 m, and the combined spacecraft will weigh 1428 kilos, of which 125 kilos are scientific instruments.

And yet, for all the cosmic significance of the space age, the images that stay in my mind from this book are the more personal, the human touches that remind

us that space travel is indeed as much about human beings as it is about robotic spacecraft. Some of these are only of personal significance to the astronauts themselves -- a Rubik's Cube (nr. 111 url), a drawing of the rocket launch site made by the son of one of the astronauts (nr. 118 url). But others are both personal and, for us, full of insights into the minds of the astronauts.

My favourites are the diaries, a mixture of observations made while in space, and notes written prior to launch. Jean François Clervoy, for example, carried a "to do" list that must be the envy of anyone reared, like me, on a diet of Dan Dare. "Dim lights, look at stars"; "look for contrails, highways, rainbows"; "feel blood pulsing"; "cycle around the world"; "tortilla frisbee". I'm guessing that Jean François was brought up on the exploits of a French character who in a couple of stories was an equivalent of Dan Dare -- Tintin!

There was a time, in the early 1970s, when I wondered whether the rapid advances in space travel technology might soon lead to an opportunity for a humble science reporter -- myself -- to make a journey into space. Well, things have not progressed quite as quickly as I had hoped, and although that technology is now sufficiently advanced, I am just too old to be a candidate for the job. This, though, is the next best thing -- a book of images that has rekindled my own sense of wonder at the Universe, and which I hope will fire that same feeling of wonder in many other people.

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