

Music of the Spheres

Charles Jenkins

My only qualification for speaking to you tonight is that I've been a professional astronomer for 21 of the 35 years that I've been paying taxes. For the rest of those years I've been an amateur astronomer and paid my taxes doing geophysics, something that surprises people, myself included. In fact I've been an astronomer longer than that; I got my first real telescope when I was 12. An early success with this instrument came when I worked out that Saturn, which I had never knowingly seen before, should be visible in the dawn sky. My long-suffering mother got up with me at 5am, and we were both well rewarded by what we saw. I'll still set up a telescope in the back yard just to look at Saturn for a few minutes. It's one of the most elegant and serene sights I know.

Many of the beautiful images we have just seen were obtained with the Hubble Space Telescope. Hubble was launched in 1990, and was the first large optical telescope to be placed in orbit, above the shimmering and trembling of the Earth's atmosphere.

Hubble has been around a long time, and took a long time to design, build and (famously) repair. When I arrived at the Cavendish Laboratory in Cambridge in 1977, up-and-coming faculty members were already defining the science mission of Hubble. Measuring the Hubble Constant, which gives the age of the Universe, was a primary task. At the time it was not known to within a factor of two, despite decades of effort; within a few years, Hubble tied it down to better than 10%.

Even at launch, Hubble was not a large telescope by Earth-bound standards; its primary mirror is about a quarter of the size of current terrestrial instruments. It's two and a half meters across. The size was determined because space-qualified mirror designs of that size were available from a couple of manufacturers in the US at the time of design in the late seventies. This probably means that there were already big telescopes in orbit, just looking down, not up.

After the fall of the Berlin Wall, some of this astro-military technology was declassified and appeared at astronomical conferences. To the civilians, it was completely astonishing. Imaging and energy-focussing technologies which seemed like impossible fantasies to us, were routine to the military scientists. I remember a telescope being described whose job was to beam laser energy to a base on the moon. Another – which I was amazed to see in action – could make images of orbiting satellites from the ground. I watched it image Hubble from a US Air Force base in New Mexico. The image that appeared was so crisp that details of the solar panels and observing hatches, familiar from spacewalk photos, were completely clear. This was the technology of President Reagan's Star Wars programme, declassified.

So, the provenance of these beautiful images is somewhat complicated. Yes, the Universe that has been revealed is a complex, intricate and astonishingly beautiful place. The human effort that has gone into investigating and understanding it is, to the same degree, inspiring. But both of these things can be seen in other ways and are somewhat ambiguous. The great achievements of basic research are contiguous with other, less inspiring achievements. There's a story of two great theoreticians, one American, one Russian, having an elliptical conversation about the X-rays that are emitted as matter falls onto black holes. The conversation was oblique because they were both perfectly aware, from their other activities, that the physical

processes at work were the same as those used for the pre-ignition implosion of a hydrogen bomb.

These beautiful images speak to an aesthetic of a certain dispassionate beauty. They are, literally, remote. They aren't images of Syria or Sudan. Even within science, they are only a part of the picture. In recent years, we have learned an enormous amount about the detailed workings of the billions of cells within our bodies. The picture that emerges – as you might expect from evolution – is of a sort of cheerful improvisation. Bits and pieces that were lying around are knocked together and if they work, it's OK. It's rather like the sort of thing I do in my garage. It's a lot more amazing, and there's a lot more of it: but a sense of lofty, elegant design is somewhat missing.

I've been an astronomer, paid or unpaid, for at least five decades. Most nights, with Walt Whitman, I'll wander out into the mystical moist night air/and look up in perfect silence at the stars. But what does this experience mean? I would like to think, with the Psalmist, that the heavens declare the glory of God. As a scientist, however, I can't avoid noticing that the psalmist's data are approached somewhat selectively. Our drive to explore this Universe is mixed up with other, less attractive things our species does, and the night sky is but one instance of what there is to be seen if we are to go looking for God's handiwork. This is an old problem, of course.

Let me speak now about hope.

It's a word that doesn't feature too well in a world where even my research plans have to be "aggressive". A "presidential hopeful" sounds like a failure in the making. Yet, we are told by the church fathers, hope is a virtue. It is not an optional extra.

As a scientist, I have a mental toolbox that, day to day, doesn't seem to have any room for hope. Science is about sitting loosely to the current state of knowledge, constantly doubting. Facts and rationality are all. This is how we are all supposed to live nowadays, and as a reaction to superstition and

authoritarianism, it's done a lot of good. However, science as a living, breathing practice is a lot more complicated than that. Creative science probably runs on hope; it's hard to know how the journey of discovery of the great minds could be sustained by anything else.

Early experimental results seemed to contradict Einstein's magnificent theory of gravity. Then I am sorry for the dear Lord, said Einstein, the theory is correct. That's the kind of attitude that I think may be what the church fathers had in mind, although with the logic inverted!

Einstein's genius selected out, from the clutter of contradictions, some insights so beautiful that he knew they just had to be true. Just last Christmas, the last of his fundamental predictions was observed, when gravitational waves were detected from a pair of merging black holes. That's a century after the theory was constructed.

I wonder if the psalmist is speaking as Einstein did, out of a determined apprehension of a truth to come.

The beauty of the night sky is not *evidence* of God's handiwork; it *is* God's handiwork, is what is being said. The psalmist is not making an observation, but an assertion.

The beautiful, elegant things we can find in the world around us – even the relaxed pragmatism of the works of evolution – these are indicators, clues amongst the clutter that Einstein wisely discarded. The world in the making is the intricate, beautiful, connected world.

The way we take hold of this is not by totting up the pros and cons, but by practicing the strong virtue of hope. It's actually the only way. The evidence – of all kinds – is ambiguous. This may be why we are told to hope; hope is what puts us in touch with the world as it is supposed to be.

Being hopeful isn't an option, it's one of the operating instructions for us to be fully ourselves in a creation that, St Paul tells us, is still being borne.

Hope is what enables us to look at the glory of the night sky, see a clue to where creation is actually headed; and begin to understand Julian of Norwich, “All shall be well, and all manner of things shall be well.”

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