Olbers' Paradox
By Paul Lewis

Introduction
According to Murdin and Penston (2004, p. 306), Olbers' Paradox asks "Why is the night sky not as uniformly bright as the surface of the Sun". They go on to explain that if the Universe is "…infinite, static and uniformly populated with stars", then irrespective in which direction the Universe is viewed, the observer should see a star. We know this does not happen and, moreover, it is a very difficult question to answer (Starchild, 2002). Understanding why this should be reveals much about the nature of the Universe. Given our advanced knowledge, though, it seems necessary to bring the paradox up to date. We now know that stars are not distributed in intergalactic space, but are only within galaxies. Nevertheless, once we move outside the Milky Way, there is no reason why galaxies should not be substituted for stars in the paradox (Berger, 2001).

The Origin of the Paradox
The infinite, static Universe has its origins in the Copernican model of the Universe. According to Hawking (1988, p. 5-6) this model was the first to dispense with the fixed celestial spheres postulated by Ptolemy. Hence the natural boundary that these spheres represented, and to which the stars were fixed, were removed. Whether the Universe was considered infinite is open to question. However, since the stars did not appear to change their position, apart from that due to the rotation of the Earth, they must be a long way away.

In 1576 Digges published a pamphlet, in which he acknowledged an infinite Universe and wondered why it did not shine with starlight (Newton, no date). (This Newton is a modern writer and not Sir Isaac Newton.) Newton also wrote about Kepler who, in 1610, recognised the problem of the dark night sky. He reasoned that if the Universe was infinite and unbounded, then the night sky should shine with starlight. Hence he realised that the Universe was bounded and finite. However the recently discovered laws of gravitation by Sir Isaac Newton, so successful in predicting planetary movements, required an infinite, homogenous Universe to prevent its gravitational collapse. Hence the bounded, finite model became unattractive to many astronomers.

Halley, in 1721, had the Universe made up of an infinite number of spherical shells, with stars evenly distributed in the spheres. As the spheres grew larger, so the number of stars increased (Harrison, 1990). Building on this, a few years later in 1744 de Cheseaux calculated that the Earth should be illuminated by starlight 180,000 more intense than sunlight. Despite the absurdity of this result, Harrison considered this to be the first proper discussion of the problem. De Cheseaux decided that some kind of interstellar medium hid most of the stars.

Olbers produced a similar argument to de Cheseaux in 1823 and it is his name that has become attached to the puzzle. As with de Cheseaux, Olbers had an interstellar medium hiding the starlight. However, if this were the case, the medium would absorb the radiation and heat up. As its temperature increased, so it would start to radiate and would, in turn, shine as bright as starlight (Wetherell, 2008).

Modern explanations
Our understanding of the Universe is rather different to the Universe as portrayed in Olbers' day. The current models of the Universe have it as finite in both size and age. As a finite

size, there is a limit beyond which there are no stars and therefore not all lines of sight will finish with a star. Furthermore the age of the Universe has been estimated to be 13.7 billion years. Therefore any stars further away than this distance in light years are simply too far away for their light to have reached us yet. In this respect it does not matter if the Universe is infinite or not; the observable Universe is finite. Newton (no date) was surprised that since Roemer had shown that the speed of light was finite in 1676, no-one made this connection until Kelvin in 1901. (In fact Newton also pointed out that both Mark Twain and Edgar Allan Poe had suggested that the Universe was finite but as mere writers, they were ignored.)

Although the paradox does not necessarily suggest an expanding Universe, an expanding Universe does suggest an answer to the paradox. As the Universe expands, so distant stars recede at ever increasing velocities and their light is red-shifted. The amount of radiation reaching us has not diminished due to the expansion, but most of it makes little, if any, contribution to visible light (Wesson, 1989). For this argument the Universe may still be infinite and the light would still be diminished by red-shift.

Most attempts at understanding the paradox are based on stars with an infinite life span. However we now know that stars have a definite life span as a bright star on the main sequence. In the case of the very largest stars, this may be only a few million years. Although very small stars may last for several tens of billions of years, average stars like our Sun will only last for about ten billion years (Green and Jones, 2004, p. 183). Even in an infinite Universe, many stars will be invisible by virtue of having reached the end of their lives on the main sequence.

The Cosmological Principle assumes that the Universe is isotropic and homogeneous. However, it has been suggested by Mandelbrot that at very large scales the distribution of stars is, in fact, fractal (BBC, 2002). This would leave dark spaces between the stars. Such an approach neither supports nor rules out the Big Bang. However it does suggest that if the Cosmological Principle does not apply, then the Earth may occupy a special place in the Universe, which might be taken to be a return to the pre-Copernican view of the Universe.

Conclusions

Although it has taken a few hundred years, there are some valid reasons why the night sky is dark. These are supported by modern ideas in cosmology. However, they can also be taken as further evidence that modern hypotheses are correct. Olbers' Paradox was based on a set of assumptions. Modern science has shown these assumptions to be false and hence provided understanding of the paradox. There is still the question of the contributions made to the paradox by various factors. For example, Wesson (1989) believes that the major contributing factor is the age of the Universe, rather than cosmological red-shift, although he admits that others disagree with him. Nevertheless both Harrison (1990) and Newton (no date) agree with this conclusion. There simply has not been enough time to flood the night sky with light.

Of course, if the Big Bang model is to be believed, then there was a period in the early Universe when the cosmic background radiation would have been in the visible spectrum, as the Universe cooled. At this time the night sky would probably have at least glowed, had there been anyone around to see it, but it would not have been due to the stars.

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