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Star Struck

Cities are not a good place to study the night sky. Urban nights are never pitch-black. There is always a light shining somewhere close by. Regimented rows of street lights, car headlights, lights from house windows, blinding security lights, the neon lights above shops and garages, LCD screens advertising this and that. Above the bright streets, low clouds reflect the city glow. Even when there are no clouds, city skies remain matt and featureless save for the occasional blinking lights of a high-flying passenger jet or, if you're very lucky, the international space station as it makes one of its silent loops 200 miles above the planet every 93 minutes.

So city folk rarely look up. There's not much to see; perhaps a handful of stars and, if it's there, the moon, of course. True, the Evening Star – the planet Venus – can defeat most light-polluted skies. Sirius, too, and Alpha Centauri can twinkle faintly in the luminescent black, if you know where to look. In the main, however, urban souls see few stars, even when they turn their eyes skywards.

People have always created light in attempts to banish the dark: fires to keep warm, ward off animals and flicker comfortingly in the middle of gathered family groups; burning torches to find your way on moonless nights along huddled streets or over open moors; candles and oil lamps to cast a dull yellow light across sitting rooms and corridors, upstairs and into bedrooms. Their light is weak and short-lived, however, and fires die out, and candles and oil lamps are snuffed as people make their way early to bed.

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First gas, then electricity changed all that. By the early nineteenth century, London, Paris and Baltimore were amongst the first cities to install street gas lights. It was Thomas Edison, though, who revolutionised the world when he created incandescent light bulbs that were robust and practical and powered by electricity. A number of other inventors had also come up with similar designs for the incandescent light bulb, most notably Joseph Swan of Newcastle, but it was Edison's design that eventually won the day. By the end of the nineteenth century, electric light bulbs could be found inside homes, illuminating shops and offices, lighting up streets and blotting out the stars.

In our 24-hour world there are fewer and fewer places where we can see the wonders of a starry night. The majority of the world's population now lives in cities. Nevertheless, if you can get away from the endless urban sprawl and off the beaten track, with not a motorway in sight, then the night sky becomes a different place. In the pens of poets, the dark becomes 'bible black', 'velvet black', 'star-studded', where a sense of the infinite invites us 'to dance beneath the diamond sky'.[1]

In attempts to recover the beauty of night skies unpolluted by artificial light, many countries have designated some of their more remote places as 'dark sky' areas. In the UK, both the Northumberland National Park and the Snowdonia Dark Sky Reserve have been recognised as International Dark Sky Places. The United States has several internationally recognised areas including Canyonlands National Park, Utah and, the darkest place of all, with no hint of understatement, the Cosmic Campground, New Mexico.

However, for large optical telescopes, the best sites for the clearest skies tend to be on the tops of mountains (less air for the starlight to shine through) in areas where the air is dry (less water to absorb the light waves). They also need to be far away from populated places. The Atacama Desert in the Chilean Andes, La Palma in the Canary Islands, Maunakea in Hawaii and the Canadian Rockies host some of the world's biggest telescopes. Blackest of all, of course, is space itself which is where we find the Hubble, Gaia, James Webb and several other telescopes.

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Before electricity and the banishment of infinite black, people would have been much more aware of stars and their profusion in the night sky. On the clearest of nights and with the sharpest of eyes, you can

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see roughly 4,500 stars if you live in the northern hemisphere and a similar number if you live in the southern hemisphere. The most spectacular sight on the darkest of moonless nights is the majestic arc of the Milky Way, our own galaxy. It contains billions of stars, but the merest fraction can be distinguished as individual points of light with the naked eye. Our galaxy appears as a hazy band of light arching across the black vault.

The breath-taking beauty of a star-strewn night sky has thrilled and fascinated people of all cultures from time immemorial. Gerard Manley Hopkins captures these feelings of excitement with the opening lines of his poem 'The Starlight Night':

> Look at the stars! look, look up at the skies!
> O look at all the fire-folk sitting in the air![2]

Similar exuberance is shown by Vincent van Gogh in his swirling interpretation, *The Starry Night*. He painted the picture in 1889 during his stay at the asylum of Saint-Paul-de-Mausole in Provence. Van Gogh painted other nocturnes that also have the power to trouble and thrill the viewer. These include the *Café Terrace at Night*, painted in Arles, and *Starry Night (Over the Rhône)*. Equally magnificent are the photographs of Ansel Adams, particularly his spellbinding *Milky Way Shining Briefly Over Banner Peak and One-Thousand Island Lake*.

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Ancient knowledge of the position and movement of the sun, moon and stars certainly helped farmers decide when to sow. It helped sailors to navigate the seas. Nearly 4,000 years ago Babylonian astrologers saw patterns in the night sky. Most early cultures believed that the planets and stars had religious significance. Priests became expert in recognising and interpreting what they observed as they looked up at the stellar-studded blackness of a desert night sky. For some the heavens were the realm of the gods. For others, the patterns of light made by the stars and the wandering of the planets had the power to foretell events down here on the Earth. This marked the beginnings of astrology, the belief that what was going on above influenced what was happening below. The idea that the date when you were born and the disposition of the stars and planets at that time determined your character gained credence.

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However, by the seventeenth century and the emergence of a scientifically based astronomy, it soon became obvious that astrology was little more than a pseudo-science. Because of their vast distances from our planet, we don't see the stars move but they do, at enormous speeds, around the galactic centre. Their position in the night sky changes, imperceptibly slowly. Given our fleeting lives, we don't notice. However, the position and patterns of the stars are constantly shifting so that in 10,000 years, a million years, a billion years, the night sky will appear different, and then different again.

Nevertheless, the early efforts that went into studying the planets and stars, for whatever reasons, did act as a stimulus to the discipline of mathematics and helped in the development of calendars, the recognition of annual cycles, and an appreciation of the rhythms of the year. It was with the aid of maths that the Polish polymath, Nicolaus Copernicus, revolutionised the way we thought about the sun and the planets. He was born on 19 February 1473 in the Polish city of Toruń. He studied and travelled throughout Europe, developing a particular interest in the stars and planets.

Although the idea that the sun might be at the centre of the celestial world had been around, off and on, for centuries, the received Aristotelian and Ptolemaic wisdom up until Copernicus's time was that the planets, sun and stars revolved around the Earth. However, whereas the stars appeared fixed in their patterns of movement, the planets shifted their position from night to night. They were known as 'wandering stars'. The six known planets would appear to weave their way amongst the stars and across constellations with no obvious logic, mathematical or astronomical. This posed major problems if you were intent on trying to model the planets as bodies that revolved around the Earth.

Copernicus had been thinking about placing the sun at the centre of the planetary system for a while but he didn't go public with his ideas. His 'heliocentric' theory made sense of why the planets appeared to move so erratically across the night skies. By placing the sun at the centre, the planets' wanderings only appeared random from the Earth's viewpoint because the Earth, too, was orbiting the sun.

One of the problems of displacing the Earth from the centre of the universe was that it went against the teachings of the Church. It was at odds with what was written in the Bible. Putting the sun at the centre of the planetary system was therefore seen as blasphemous and, if voiced, could incur severe penalties, including the possibility

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of death. However, by 1543 when he was nearly seventy years of age, Copernicus decided to publish his mathematical description of the sun, moon and planets. *De revolutionibus orbium coelestium* (*On the Revolutions of the Heavenly Spheres*) described the planets, including the Earth, as a single system circling the sun.[3] In the book, he writes:

> [The sphere of the fixed stars] is followed by the first of the planets, Saturn, which completes its circuit in 30 years. After Saturn, Jupiter accomplishes its revolution in 12 years. Then Mars revolves in 2 years. The annual revolution takes the series' fourth place, which contains the Earth … together with the lunar sphere as an epicycle. In the fifth place Venus returns in 9 months. Lastly, the sixth place is held by Mercury, which revolves in a period of 80 days.

He went further and suggested that the universe is much larger than was previously thought. Astronomical distances, he said, were vast. In an instant, the universe and our tiny place in it, was transformed. No longer were men, women and the Earth at the centre, with the rest of the universe spinning around us in neat, ever-widening circles. We were displaced. This would not go down well with the religious authorities. Unfortunately, or perhaps fortunately, Copernicus died later that year on 15 May 1543 in his native Poland.

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Not long after the death of Copernicus, the study of the stars was about to receive another huge boost. For a while, Dutch lens makers had been producing some of the best glass lenses in the world for fitting into spectacles. The microscope had been invented and the world of the very small was being revealed in marvellous detail.

'Spyglasses' or telescopes were also in development allowing the far away to appear near and close. The first person to apply for a patent for a telescope was a Dutch eyeglass-maker named Hans Lippershey in 1608, although there was fierce rivalry between Lippershey and some of his fellow countrymen, including Zacharias Jansen and Jacob Metius about who made the best, if not the first telescope.[4]

Born in Pisa in 1564, the same year as William Shakespeare, the young Galileo Galilei began to develop an interest in natural philosophy. Galileo soon established himself as an expert in physics,

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engineering and mathematics. His skills as a lens grinder allowed him to make improvements to the recently invented microscope.[5] When he heard about the Dutch 'perspective glasses', he set about making his own telescopes. By 1609 his improvements were allowing him to magnify distant objects 20 to 30 times, a significant increase in power over other telescopes around at the time. However, whereas most 'spyglass' enthusiasts were training their telescopes horizontally to look out for ships on the horizon on their way into port or to spy enemy soldiers lining up on distant hillsides, Galileo turned his telescope up, vertically, to look at the sky.[6]

His powerful telescopes were soon revealing 'stars in their myriads', ten times as many as had ever been seen by the naked eye. Suddenly, the universe was not only bigger than previously thought, but teeming with stars, far more than ever had been imagined.

Copernicus had based his ideas of a heliocentric solar system on getting the planetary mathematics to add up. In contrast, Galileo developed his understanding of the stars and planets by making observations using his increasingly powerful telescopes. His approach marked the birth of astronomy as an empirical science. In no time at all he was seeing craters on the moon, dark spots on the sun, phases of Venus, rings around Saturn, moons spinning about Jupiter and a band of light arcing across the clear black, night sky that we now know is an end-on view of our own galaxy, the Milky Way.

In 1592 he moved to the Venetian city of Padua where he took the chair in mathematics. However, it was as a practical scientist that it became clear to Galileo that Copernicus was right. The Earth could no longer be seen as the centre of the universe. Along with the other planets, it revolved around the sun. The Roman Catholic Church continued to view such ideas as heretical. Any challenge to its view of the world and its divinely ordained hierarchy was a challenge to its authority. Under threats from the Church, Galileo had to back-pedal. Although he was allowed to discuss the sun-centred view of the universe as a philosophical idea, he could not openly endorse it. For a while, he played safe and kept quiet. Gradually, however, it seemed as if the religious authorities might be growing more tolerant of debates about how the cosmos might be structured.

In 1632, Galileo thought he had gained papal approval to publish his book, *Dialogue Concerning the Two Chief World Systems*, in which he could mention helio-centrism but certainly not support it. However, he was up against powerful forces who would have no

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