Contents

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Page 9: Baily's beads; Luc Viatour / https://Lucnix.be
Page 63: 2016 Coronal mass ejection; NASA
Page 85: US astronaut Buzz Aldrin; NASA
Page 98: Comet 67P; ESA / Rosetta / NAVCAM
Page 105: Saturn's rings taken by the Cassini wide-angle camera; NASA / JPL / Space Science Institute
Page 116: Orbital predictions diagram created by Worldwide Telescope; Caltech / R. Hurt (IPAC)
Page 136: Crab Nebula; NASA / STScI / ESA
Page 174: AMS-02; NASA
Page 204: CMB; WMAP Science Team / NASA
Page 224: Type 1A supernova exploding; NASA / ESA / HUBBLE / HIGH-Z SUPERNOVA SEARCH TEAM

Introduction

'I have loved the stars too fondly to be fearful of the night.'

The Old Astronomer (To His Pupil), Sarah Williams (1868)

I've been captivated by the night sky for as long as I can remember. It was the first time I ever fell in love. As children we are told wonderful stories of goblins, dragons and witches, but the universe has always been more magical to me than any fairy tale.

Generations of astronomers have pulled back the curtain from the cosmos and revealed its innermost secrets. What they've found is nothing short of incredible. Countless planets dance around an endless expanse of stars. Gravity twists and curls space until time itself grinds to a halt. We can follow atoms on a journey all the way from the heart of stars to your skin and bones. We've sent machines to every planet in the solar system and left our footprints in the lunar dust.

The sheer scale of such a universe can be intimidating. I've spent the last ten years writing and speaking about astronomy and it still makes me feel small. A lot of people are put off because they assume learning about it must be difficult. But it doesn't need to be. The aim of this book is to break the vastness of space down into digestible

pieces that are easy to understand. There's no maths or jargon here, just simple explanations of the universe's most fascinating features.

I've included as much about what we don't know as what we do. Answering one question throws up many others. We still don't understand what most of our universe is made of or whether we share space with any other life forms. Astronomers are still trying to figure out if our universe is the only one and exactly how space and time got started. These are some of the most fundamental questions it is possible to ask.

The book is organized in order of increasing distance from Earth, starting with our earliest astronomical discoveries before heading out into the wider solar system and then to the galaxy and universe(s) beyond. Our travels will cover 93 billion light years of space and nearly 14 billion years of time. I have carefully selected our itinerary so that you can hold the entire universe in your hand and discover what interests you most along the way.

So join me on a journey across the cosmos. I hope you will fall in love with the night sky, too.

CHAPTER 1

Early Astronomy

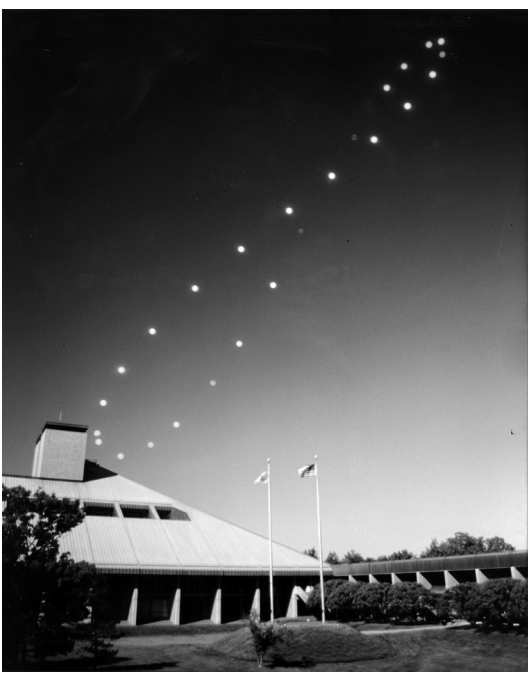
Marking the passage of time

Long before the sky was a place of planets, galaxies and black holes it was the realm of gods and omens. A crack of thunder could signal Almighty displeasure; a passing comet was an ominous harbinger of doom. At least that's how many of our ancestors saw it.

But the sky's most important role was as a natural timepiece. In the aeons before clocks, computers and smartphones, our predecessors noticed that the sky ticked out its own natural rhythm. The sun would come and go over a period they came to know as a day. They gathered together seven of these days to form a week, with each day named after one of the seven celestial objects they saw behaving differently to the stars (see page 18).

The moon changed its appearance, waxing and waning through phases, growing from a tiny crescent to a dazzling full moon and back again. One cycle of this shape-shifting took almost thirty days, a period they called a 'moonth'. The relentless morphing of language over time has seen us lose a letter. The sun, too, executes a much longer cycle. Rising each morning towards the east, and setting towards

the west in the evening, it reaches the peak of its daily climb at midday. Yet its height above the ground at noon is not always the same. Watch over many months and you'll see the sun trace out a figure-of-eight shape in the sky called an 'analemma'. In the time it takes to complete this particular cycle the sun rises 365 times. The ancients called this cycle a year. This period was divided into four seasons, each with its own distinct weather trends. Winter, spring, summer and autumn were seen to repeat in the same time as the analemma took to complete.



The sun appears to trace out a 'figure of eight' in the sky over the course of a year. Astronomers call it an analemma.

By 10,000 years ago we were building massive clocks to keep up with the sky's natural rhythms. In 2004, a team of archaeologists discovered an ancient Stone Age site in Scotland dating from this time. By 2013 they had realized why it was built. The architects of the site dug twelve pits along an arc 50 metres long – one for each of the twelve complete lunar cycles which normally fit into a year (occasionally there can be thirteen full moons in a year if the first falls in early January). Five thousand years later, stonemasons began work on the mighty circle of Stonehenge on Salisbury Plain, in England. Standing inside the circle, you see the sun rise directly above one particular stone – the heel stone – on the day when it reaches the top of the analemma (the summer solstice).

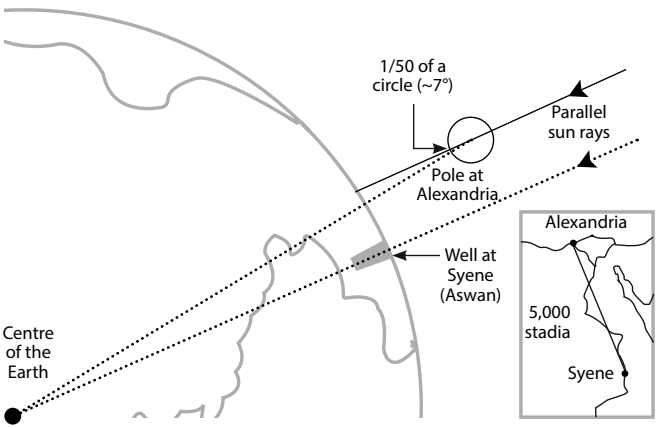
Today we go about our hectic, modern lives in the digital age largely unaware of the rhythm of the sky. But for ancient civilizations it was the only way of measuring time, and their extensive studies of the movements of the sun and the stars form the basis of how we organize our lives today.

Discovering the shape of the Earth

Don't believe anyone who tells you that the best minds of the Middle Ages believed the world was flat – we knew that it wasn't more than 2,000 years ago. The man we have to thank for that knowledge is Ancient Greek mathematician Eratosthenes, and he figured it out without ever leaving Egypt.

He noted that in the Egyptian city of Syene the sun was directly overhead at noon on the summer solstice. His genius was to make a measurement of the sun at exactly the same

time on a subsequent summer solstice in the city of Alexandria, some 800 kilometres away. By placing a stake in the ground, and looking at its shadow, he could see that the sun struck his stake not from overhead but at an angle of seven degrees. The reason for this difference is that the Earth's surface is curved, meaning the sun's light strikes each city at a different angle.



Eratosthenes worked out the size of the Earth by looking at the angle of shadows from different locations in Egypt.

He went one step further. If a distance of 800 kilometres causes a seven-degree difference, he could scale that up to see the distance represented by a full 360 degrees. That gives the circumference of the Earth as just over 41,000 kilometres (he did his calculations using an ancient unit of distance called the 'stadion', so his answer was actually approximately 250,000 'stadia'). He was within 10–15 per cent of our modern value for the Earth's size. So not only did the Ancient Greeks know the Earth was round, they also had a pretty good idea about how big it was, too.