SAMPLE

Earth's Sky: The Northern Lights

Auroras and the Solar Wind

Aira Astralis

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Conclusion

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Introduction

High above the polar regions of the Earth, the sky itself begins to glow. Curtains of green light hang from the darkness, folding and rippling like fabric in a slow wind. Rays shoot upward in silent columns; edges brighten and fade; and in the most powerful displays, the whole heaven burns with red, violet, and blue. People have watched these lights for as long as there have been people near the poles, and for most of that history, no one knew what they were looking at. This book is about the northern lights (the aurora borealis) and about the long human effort to understand them.

They are, in plain terms, light emitted by the upper atmosphere when energetic particles from space rain down along Earth's magnetic field lines and collide with gases tens to hundreds of kilometers overhead. That single sentence took thousands of years to write. Behind it stands a story that runs from Roman chronicles and Norse legend, through the patient expeditions of a Norwegian scientist who hauled magnets across the Arctic, to fleets of satellites that now watch the lights from above while radar stations watch from below. The northern lights begin, oddly enough, at the Sun.

Our star constantly throws off a stream of charged particles (the solar wind) which flows outward past the planets at hundreds of kilometers per second. When that wind encounters Earth's magnetic field, it stretches the field into a long tail on the night side, stores energy in it, and releases that energy in bursts that hurl particles down into the upper atmosphere near the poles. There, the particles strike atoms and molecules of oxygen and nitrogen, and the atoms answer with light: green and red from oxygen, blue and violet from nitrogen. The lights are the atmosphere's own phosphorescence, powered by a stormy Sun and steered by the Earth's magnetism.

Auroras are also the visible face of space weather. The same bursts that light the sky can disturb satellites, garble radio communication, and (in the most extreme storms) push electric currents into power grids strong enough to black out cities. Learning to read the aurora was, historically, learning to read our planet's electromagnetic environment; forecasting the aurora today is one front of a broader effort to forecast the weather in space. This book follows the standard structure of the series. We will begin with discovery: how ancient and medieval observers described the lights, and how Enlightenment science slowly connected them to magnetism and, eventually, to the Sun.

We will then explain the aurora itself (its causes, its colors, its shapes and behavior) and the instruments and missions used to observe it. We will place the aurora in its larger context of solar storms and space weather, review the

modern understanding and the great research programs behind it, and count the discoveries that changed the field. We will look honestly at the questions still unresolved, at where research is heading, and at the folklore, records, and trivia that make the northern lights a cultural phenomenon as much as a scientific one. A concluding chapter draws the threads together.

One idea runs through everything: the aurora is where the invisible becomes visible. Magnetic fields, electric currents, solar storms, none can be seen directly. But over the poles, the sky traces them in light. To study the northern lights is to watch our planet's shield against space at work, beautiful, dynamic, and written in colors that anyone with clear eyes and a dark night can read.

Chapter 1: The

Discovery of The Northern Lights

The northern lights have been observed for as long as humans have lived beneath the polar sky, but recognizing them for what they are (a natural phenomenon of the upper atmosphere, not omens or spirits) was a slow journey through legend, record-keeping, and physics. The oldest written descriptions are scattered through the chronicles of ancient civilizations. Chinese annals from centuries before the common era record nighttime "red vapors" and "white ribbons" in the sky, some of which were almost certainly auroras, though comets and atmospheric glows make identification uncertain. The Greek and Roman world knew the lights too, usually at their redder and more violent extremes: large solar storms push the auroral oval far toward the equator, and the Mediterranean saw such displays often enough for Roman writers to mention them.

The natural philosopher Seneca, in the first century, devoted a section of his Questions about Nature to the lights, listing earlier reports: heavens that seemed to burn, divided by rays; a light that lit up the night over the port town of Ostia so convincingly red that a detachment of soldiers (on fire-watch duty) galloped off to rescue a city that was not, in fact, burning. Seneca's conclusion was remarkable for its time: the lights, he argued, belonged to the upper air and should be studied rather than feared, and their colors should be measured, a program of auroral science written nineteen centuries early.

Medieval Europe mostly saw the aurora through Christian eyes, and the chronicles record it as armies in the sky, burning spears, or signs of divine displeasure, unsurprising in an age when the lights at mid-latitudes usually appeared during great storms, blood-red and terrifying. Norse tradition took a different view: in Old Norse literature the lights are mentioned rarely, but in the later Scandinavian and Icelandic folk imagination they were connected with the dead, with shimmer of armor, and with the fires of the far north. What is certain is that the peoples who lived under the lights every winter (the Sami of northern Scandinavia, the various peoples of the Arctic coast) treated them as familiar neighbors, weaving them into stories with rules for behavior: some traditions said the lights should be treated with respect and not mocked or whistled at, for the lights might take offense.

We will return to folklore in a later chapter. The scientific turn began in the seventeenth and eighteenth centuries, and it came through a coincidence of geography and magnetism. In 1621, the French scholar Pierre Gassendi described a bright auroral display visible from southern France and gave the

phenomenon its enduring name: "aurora borealis" (northern dawn) a name usually credited to Galileo Galilei, who had used the same phrase in 1619.

The name stuck because it captured what mid-latitude observers most often saw: a red glow on the northern horizon at dawn-like hours. The breakthrough link was to magnetism. Edmond Halley (of comet fame) after the great auroral displays of 1716 and 1717, proposed that the lights were connected with the Earth's magnetic field and with a magnetized vapor rising from the globe's interior; his geometry, involving magnetic poles, was startlingly close to the modern idea. In the 1740s, the Swedish astronomers Anders Celsius and Olof Hiorter made the decisive observation: they recorded, hour by hour, that the aurora and the compass needle moved together, when the lights danced, the needle trembled.

Aurora and geomagnetism were two faces of the same phenomenon. By the end of the eighteenth century, observations coordinated across Europe (including the remarkable records of the 1770s collected by the French Academy of Sciences) had established the lights as a global, magnetically organized phenomenon in the upper atmosphere. The nineteenth century brought the first quantitative programs. The great geomagnetic observatory network (Gottingen, Toronto, and stations beyond) showed that auroras and magnetic storms occurred together worldwide, and the invention of the spectrocope in 1859 let astronomers ask what the light was made of. The very year of the Carrington solar storm (1859) a Swedish physicist, Anders Jonas Angstrom, obtained the first auroral spectrum: a green line whose origin would puzzle scientists for seventy years.

Meanwhile the polar explorers brought back systematic notes: John Franklin's overland expeditions in northern Canada kept careful aurora journals in the 1820s, and the 1830s-40s saw observers such as the Norwegian Christopher Hansteen argue that the aurora formed a ring around the magnetic pole, a hint of the auroral oval. The discovery of the aurora's true cause begins with one man: Kristian Birkeland. Beginning in 1899, the Norwegian physicist mounted expeditions into the Arctic night (stations across the far north of Norway and the surrounding seas) measuring the aurora, the magnetism beneath it, and the currents it implied.

His masterstroke was the terrella: a magnetized sphere in a vacuum chamber, bombarded by cathode rays (electrons) which glowed in rings around its magnetic poles, a laboratory model of the Earth and its lights. From this work Birkeland concluded that the aurora was caused by electrons streaming from the Sun, guided by Earth's magnetic field into the polar regions along field-aligned electric currents. The scientific establishment (led by the British

physicist Sydney Chapman, who preferred currents flowing only in the upper atmosphere itself) rejected the idea of particles from space for decades.

Birkeland died in 1917, before his vindication; satellites in the 1960s measured the currents flowing along magnetic field lines into the aurora, and today they are called Birkeland currents.

That is the discovery arc: from omens in the chronicles, to a name, to the link with the compass needle, to the spectrum, to the electron. Each step required a new instrument (the pen, the compass, the spectroscope, the magnetized sphere, the satellite) and each opened the next question. The chapters that follow unpack what all those instruments finally revealed. A closing note belongs in this chapter about the long gap between seeing and understanding. It is tempting, from the modern side of the story, to wonder what took so long: the lights were overhead every winter for the whole of human history.

The answer is that the aurora hides its nature behind three obstacles. First, at the latitudes where science was done, it is rare, the strong displays that reach the mid-latitudes come only with great storms, and the everyday aurora lives beyond the horizons of the observatory era's great cities. Second, it is a phenomenon of the upper atmosphere and of electricity, two domains that had to be invented before the lights could be explained; there was no vocabulary for field-aligned currents until there were fields, currents, and a magnetosphere to name. Third, it is planetary: understanding the oval required simultaneous observations from many places at once, which is why the decisive advances came with the telegraph (coordinated clocks), the Polar Years (coordinated stations), and satellites (the global view). The aurora was never hidden by darkness alone; it was hidden by the absence of the instruments and institutions that eventually answered it.

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ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.