The History of Astronomy

A Field Guide to Who, When, and Why

Four thousand years of sky, in four parts.

whatsuptonight.ca

Why this guide

What you look at tonight has 4,000 years of story behind it.

When you find M31 in your eyepiece — that faint smudge of light in Andromeda — you're seeing something humans didn't even know was *outside our own galaxy* until the mid-1920s. Edwin Hubble had to spend months at the 100-inch Hooker telescope on Mount Wilson tracking a single Cepheid variable he first flagged on a plate in October 1923, then a dozen more, before anyone could prove that smudge sat far outside the Milky Way. Before that, it was just another nebula in the catalog.

The Crab Nebula in Taurus is the still-glowing wreckage of a star that Chinese imperial astronomers watched explode in July 1054. Saturn's rings baffled Galileo when he saw them in 1610 — his telescope wasn't sharp enough to resolve them, and he thought Saturn had ears. It took until 1655 for Christiaan Huygens to figure out what they actually were.

Every object on your observing list is a story. This guide is here to put the stories alongside the targets — the people who first saw, the moments when something clicked, the long arc of how we came to know the sky.

It's in four parts. **The Timeline** walks 4,000 years of astronomy in five eras — ancient, optical, deep-sky, astrophysics, and modern. Each is a quick reference grid of dates and events. **Astronomers Worth Knowing** profiles thirty-four people whose work changed what we understand. Some are household names. Others should be. The mix is deliberate. **Discovery Stories** tells eight longer tales tied to objects you can actually see — the supernova that became the Crab, the proof that Andromeda was a galaxy, the eclipse that confirmed Einstein, the long puzzle of Saturn's rings, the mathematical prediction of Neptune, the canals on Mars that turned out not to be there, the patient search for Pluto, and the accidental detection of the cosmic microwave background. **What We Inherited** closes the guide by following the threads from all of that history into the clock on your wall, the calendar on your phone, and the GPS that's quietly using Einstein to find you a coffee shop.

The hope is that the next time you point your scope at something old, it feels a little less like looking at a smudge and a little more like joining a conversation that's been going on for a very long time.

Part 1 — The Timeline

Four thousand years of astronomy in five eras. Each is a quick-reference grid of dates and events — the milestones to know, organized so you can flip back to them. Read it through once, then keep it as a reference.

The Ancient Sky

c. 1600 BCE – 1500 CE

Before the telescope, the sky was the only visible part of the universe. Humans across cultures spent thousands of years recording, predicting, and explaining its motions with nothing but their eyes.

c. 1000 BCE	Babylonian astronomers compile the Mul.Apin tablets — a catalog of stars and predictions of planetary positions, building on observing traditions that reach back nearly a thousand years earlier.
c. 1100 BCE	Chinese astronomers begin systematic records of celestial events, including comets and eclipses.
585 BCE	Thales of Miletus reportedly predicts the solar eclipse of May 28th.
c. 280 BCE	Aristarchus of Samos proposes a heliocentric model. Largely ignored.
c. 240 BCE	Eratosthenes measures the circumference of the Earth from shadow angles at Syene and Alexandria — correct within a few percent.
c. 150 BCE	Hipparchus produces the first systematic star catalog and discovers the precession of the equinoxes.
150 CE	Ptolemy's *Almagest* establishes the geocentric model that will dominate for 1,400 years.
964 CE	al-Sufi's *Book of Fixed Stars* contains the first written description of the Andromeda Nebula (M31).
1054 CE	Chinese imperial astronomers record a 'guest star' in Taurus, visible in daylight for 23 days and at night for nearly two years. The progenitor of the Crab Nebula.
1066 CE	Halley's Comet appears on the Bayeux Tapestry as an omen before the Battle of Hastings.
1543 CE	Nicolaus Copernicus publishes *De revolutionibus*, reviving heliocentrism on his deathbed.
1600 CE	Giordano Bruno burned at the stake in Rome for (among other heresies) defending an infinite universe of inhabited worlds.

The Optical Revolution

1600 – 1750

In a single human lifetime, the telescope transformed the sky from a vault of fixed lights into a universe of worlds. The first decades of telescopic astronomy produced more new knowledge than the previous twenty centuries combined.

1608	Hans Lippershey applies for a patent on the first telescope in the Netherlands.
1609	Galileo turns a telescope on the sky for the first time.
1610	Galileo publishes *Sidereus Nuncius*: mountains on the Moon, four moons of Jupiter, individual stars in the Milky Way. By year-end he will have also seen the phases of Venus.
1610	Galileo first sees Saturn's rings but cannot resolve them; describes Saturn as 'triple-bodied.'
1611	Sunspots independently observed by Galileo, Christoph Scheiner, and Thomas Harriot.
1633	Galileo tried by the Roman Inquisition for defending heliocentrism; forced to recant, sentenced to house arrest for life.
1655	Christiaan Huygens identifies Saturn's rings as a flat disk and discovers Titan.
1671	Giovanni Cassini discovers Iapetus, the first of four Saturn moons he will find.
1675	Cassini identifies the dark gap in Saturn's rings that bears his name — the Cassini Division.
1687	Isaac Newton publishes *Principia Mathematica*, establishing universal gravitation and explaining Kepler's laws.
1705	Edmond Halley uses Newton's gravity to predict the return of a comet (confirmed posthumously, 1758).
1729	James Bradley discovers stellar aberration — the first direct proof that Earth moves through space.

The Deep-Sky Era

1750 – 1900

Bigger telescopes, longer nights. With Newton's physics in hand and reflecting telescopes growing in aperture, astronomers turned to the nebulae and star clusters that the early observers had passed over.

1758	Charles Messier finds a fuzzy patch in Taurus while comet-hunting. It becomes M1, the first entry in his catalog.
1781	William Herschel discovers Uranus — the first planet found in recorded human history.
1783	William Herschel measures the Sun's motion through space toward the constellation Hercules.
1786	Caroline Herschel begins her own catalog of nebulae and discovers the first of her eight comets.
1801	Giuseppe Piazzi discovers Ceres, the first asteroid.
1838	Friedrich Bessel measures the parallax of 61 Cygni — the first stellar distance ever measured, about 10.4 light-years.
1846	Neptune discovered through mathematical prediction by Le Verrier and Adams; observed by Galle within hours of receiving Le Verrier's letter.
1864	William Huggins uses spectroscopy to prove that nebulae are made of gas and that stars share Earth's chemical elements.
1868	Helium is discovered in the spectrum of the Sun before it is found on Earth.
1888	John Dreyer publishes the New General Catalogue (NGC) of 7,840 deep-sky objects.

The Astrophysics Era

1900 – 1960

Astronomy stopped being only mapping and became *physics*. Spectroscopy, photography, and the first space-borne instruments revealed not just where the objects are but what they are made of and how they work.

1912	Henrietta Leavitt discovers the period-luminosity relation of Cepheid variables — astronomy's first cosmic yardstick.
1911–13	The Hertzsprung–Russell diagram — plotting stars by luminosity vs. temperature — emerges; it becomes the central organizing tool of stellar astrophysics.
1916	Albert Einstein publishes general relativity. Karl Schwarzschild works out the first exact solution; it describes black holes, decades before anyone believes in them.
1919	Eddington's eclipse expedition confirms Einstein's prediction that gravity bends starlight.
1920	The 'Great Debate' — Shapley vs. Curtis on whether spiral nebulae are inside or outside the Milky Way.
1923–25	Edwin Hubble identifies a Cepheid variable in M31 (October 1923; announced January 1925), proving Andromeda is a separate galaxy. His original distance of about 900,000 light-years was later revised upward to 2.5 million after Baade's 1952 recalibration.
1925	Cecilia Payne's thesis demonstrates that stars are overwhelmingly hydrogen and helium.
1929	Hubble announces that distant galaxies are receding at speeds proportional to distance — the universe is expanding.
1930	Clyde Tombaugh discovers Pluto after a year of blink-comparator work at Lowell Observatory.
1931	Karl Jansky detects an unexplained radio hiss at Bell Labs; by 1933 he has traced it to the center of the Milky Way, founding radio astronomy.
1933	Fritz Zwicky proposes 'dark matter' to explain galaxy cluster dynamics.
1957	Sputnik launched. The space age begins.
1959	Luna 3 photographs the far side of the Moon for the first time.
1962	Riccardo Giacconi's rocket flight detects Sco X-1, the first cosmic X-ray source: birth of X-ray astronomy.

The Modern Era

1960 – today

Telescopes left Earth. Astronomy now works across the whole electromagnetic spectrum — and increasingly beyond it, with neutrinos and gravitational waves joining light as ways of seeing the universe.

1964	Penzias and Wilson accidentally detect the cosmic microwave background — leftover heat of the Big Bang.
1967	Jocelyn Bell Burnell discovers the first pulsar. Her supervisor wins the Nobel; she does not.
1968	Apollo 8 astronauts photograph 'Earthrise' from lunar orbit on Christmas Eve — the most influential image in environmental history.
1969	Apollo 11 returns the first lunar samples. Humans walk on another world.
1970s	Vera Rubin's rotation-curve measurements make dark matter undeniable.
1986	Halley's Comet returns and is visited by an international armada of six spacecraft (the Soviet Vegas, Japan's Sakigake and Suisei, ESA's Giotto, and NASA's ICE).
1987	Supernova 1987A is discovered photographically by Canadian astronomer Ian Shelton at Las Campanas (and independently spotted visually by Oscar Duhalde the same night) — the closest naked-eye supernova since Kepler's of 1604.
1990	Hubble Space Telescope launched (and famously found to have a flawed mirror).
1992	Aleksander Wolszczan discovers the first confirmed exoplanets, orbiting a pulsar.
1992	The COBE satellite maps tiny temperature ripples in the cosmic microwave background — the seeds of all later cosmic structure.
1995	Mayor and Queloz find 51 Pegasi b — the first exoplanet around a Sun-like star.
1998	Two independent teams find the universe's expansion is accelerating: dark energy.
2015	LIGO detects the first gravitational waves, from a black hole merger 1.3 billion light-years away.
2019	The Event Horizon Telescope publishes the first image of a black hole's shadow (M87*).
2021	James Webb Space Telescope launched.
2024	Total solar eclipse crosses North America on April 8th, observed by tens of millions.

Part 2 — Astronomers Worth Knowing

Thirty-four people whose work changed what we understand about the sky. Some are household names. Others should be. The mix is deliberate — the Harvard Computers (Cannon, Leavitt, Payne) did as much for modern astrophysics as anyone in this list, and Helen Sawyer Hogg gave Canadian astronomy six decades of patient work and a newspaper column that pulled an entire generation into the sky.

Eratosthenes

c. 276 – c. 194 BCE

Alexandria

Measured the size of the Earth

Chief librarian at the great Library of Alexandria and one of the most quietly ambitious thinkers of antiquity. The Greeks had known for at least two centuries that the Earth was a sphere — ships disappearing hull-first over the horizon, the curved shadow Earth casts on the Moon during a lunar eclipse, the way stars rise at different angles from different latitudes. What no one had done was *measure* it. Eratosthenes did. Hearing that at noon on the summer solstice the Sun shone straight down a well in Syene (modern Aswan), casting no shadow, he measured the angle of the Sun's shadow in Alexandria on the same day — about seven degrees from vertical. He knew the distance between the two cities. Simple geometry gave him the Earth's circumference at roughly 252,000 stadia. The exact value depends on which stadion he meant, but his answer was within a few percent of the modern figure. The result was lost to medieval Europe but survived in Arabic translations — and was the figure Columbus stubbornly disbelieved when he set sail.

Hipparchus

c. 190 – 120 BCE

Nicaea / Rhodes

First systematic star catalog

The greatest astronomer of antiquity. Working from Rhodes with nothing but his eyes, a sighting tube, and patience, Hipparchus catalogued the positions and brightnesses of about 850 stars. The magnitude scale you still use to describe how bright a star is is his. By comparing his measurements with Babylonian observations two centuries older, he detected the precession of the equinoxes: a slow wobble of Earth's axis with a 26,000-year period. He did this without realizing Earth moved at all.

Claudius Ptolemy

c. 100 – c. 170 CE

Alexandria

The Almagest and the geocentric system

Working in Greek-speaking Roman Egypt, Ptolemy synthesized seven centuries of Hellenistic astronomy into one comprehensive work: the *Mathematike Syntaxis*, later known by its Arabic title, the *Almagest*. It was a complete mathematical system for predicting the motions of the Sun, Moon, planets, and stars — built around a stationary Earth at the center of a lattice of epicycles and deferents. He was wrong about the architecture, but his predictions were accurate enough that the *Almagest* served as the working textbook of astronomy for 1,400 years. It was preserved by Islamic astronomers, translated into Latin in the 12th century, and only displaced by Copernicus. His star catalog of 1,022 entries was the standard until Tycho. Whatever else he got wrong, he wrote the longest-lived textbook in the history of science.

Aryabhata

476 – 550

India (Kusumapura)

Earth rotation, accurate astronomy from India

Indian mathematician and astronomer who proposed, a thousand years before Copernicus, that the apparent daily motion of the stars was caused by Earth rotating on its own axis — the stars themselves staying still. His treatise *Aryabhatiya*, written when he was twenty-three, gave a sidereal year of 365 days 6 hours 12 minutes (only three minutes off the modern value), correctly explained eclipses as shadows rather than mythological events, and computed pi to four decimal places. His ideas reached the Islamic world and influenced al-Khwarizmi, traveling west from there. India's first artificial satellite was named for him in 1975.

al-Sufi

903 – 986

Persia (Isfahan)

First description of M31 and the LMC

The medieval Islamic world preserved and extended Greek astronomy while Europe slept. Abd al-Rahman al-Sufi's *Book of Fixed Stars* (964 CE) is the link between Ptolemy and the European Renaissance. It contains the first written description of the Andromeda Nebula — a 'little cloud' — and the Large Magellanic Cloud, 'al-Bakr,' the white ox. For nearly a thousand years, al-Sufi was the only astronomer who had looked carefully at the deep sky.

Nicolaus Copernicus

1473 – 1543

Poland (Frombork)

Put the Sun back at the center

A Catholic canon, physician, and quiet revolutionary. Copernicus put the Sun back at the center of the solar system eighteen centuries after Aristarchus had done so and been ignored. He worked on *De revolutionibus orbium coelestium* for nearly thirty years in private, reluctant to publish — he knew it contradicted both Ptolemy and the Church. Legend has it the printed book was placed in his hands on the day he died in May 1543. His model still relied on circular orbits and was no more accurate than Ptolemy's at predicting planetary positions, but it changed the question. The old question was 'how do the planets move around us?' The new one was 'where does Earth sit among them?' That question was the one that made everything else — Kepler, Galileo, Newton — possible.

Tycho Brahe

1546 – 1601

Denmark

Pre-telescope precision

The last great naked-eye astronomer and arguably the best observational instrument any single human ever was. Tycho built his own observatory on the island of Hven and produced positional measurements ten times more accurate than anything before him — accurate enough that when Kepler later inherited the data, it forced him to abandon circular orbits. Tycho famously lost his nose in a duel and wore a brass prosthetic. He died in 1601 of a burst bladder, after a banquet where etiquette forbade leaving the table.

Giordano Bruno

1548 – 1600

Italy (Nola) / Europe

Infinite worlds; killed for the vision

A Dominican friar with a restless mind and a long tongue. Bruno spent his life running from one European city to another teaching philosophy and arguing for an infinite universe filled with countless other worlds, each with its own Sun and its own inhabitants. He had read Copernicus and gone much further than Copernicus had dared. In 1592 the Roman Inquisition arrested him. After eight years of trial and refusal to recant, he was burned alive at the stake in Rome's Campo de' Fiori on February 17, 1600. He was not strictly an astronomer — his evidence was philosophical, not observational — but the universe we now know is essentially the one he described, with hundreds of billions of stars and other planetary systems beyond counting. A bronze statue of him stands today in the square where he died.

Galileo Galilei

1564 – 1642

Italy

First astronomical use of the telescope

In 1609, Galileo turned a telescope upward and changed everything. Over the next year he saw mountains on the Moon (the Moon was a *place*), four worlds orbiting Jupiter (not everything orbits Earth), the phases of Venus (proof Venus orbited the Sun), individual stars in the Milky Way (the universe was bigger than anyone thought), and the rings of Saturn (which he couldn't resolve and described as 'handles' or a 'triple-bodied' planet). In 1632 he published *Dialogue Concerning the Two Chief World Systems* — a side-by-side comparison of the Ptolemaic and Copernican models that was clearly a victory lap for heliocentrism, and a direct challenge to the Church. The Roman Inquisition put him on trial the next year. At sixty-nine, threatened with torture, he was forced to kneel and recant. Legend says he muttered '*eppur si muove*' — 'and yet it moves' — under his breath as he stood. There is no evidence he actually said it, but it is the line history wanted him to have. He was sentenced to house arrest at his villa near Florence and spent the last nine years of his life there, going blind and writing on physics. The Catholic Church formally acknowledged the case had been mishandled in 1992.

Johannes Kepler

1571 – 1630

Germany / Prague

Laws of planetary motion

Inheriting Tycho Brahe's data after Tycho's death, Kepler spent eight years on the orbit of Mars before giving up on circles. His three laws — that planets orbit in ellipses, that they sweep equal areas in equal times, and that orbital period scales with the cube of distance — finally gave humanity a working description of the solar system. They would later become the test case for Newton's gravity. Kepler also believed in astrology, calculated horoscopes for a living, and wrote one of the first works of science fiction.

Maria Cunitz

1610 – 1664

Silesia (now Poland)

Made Kepler usable; 'the Second Hypatia'

Working from a small town in Silesia while Europe burned through the Thirty Years' War, Maria Cunitz wrote one of the most useful astronomical works of the 17th century: *Urania Propitia* (1650). It was a translation, simplification, and correction of Kepler's notoriously dense *Rudolphine Tables* — the standard tool for computing planetary positions. Cunitz made Kepler's work usable by ordinary astronomers and fixed mathematical errors along the way. She wrote in both Latin and German, an unusual move that put astronomy within reach of non-scholars. Her contemporaries called her 'the Second Hypatia.' Asteroid 12624 Mariacunitia is named for her.

Johannes Hevelius

1611 – 1687

Danzig (Gda■sk)

First detailed atlas of the Moon

A wealthy brewer and city councillor who built one of the great private observatories of his century on the roofs of three of his own houses in Danzig. Hevelius spent years mapping the Moon at the eyepiece, naming its features and producing *Selenographia* (1647) — the first detailed lunar atlas, with engravings good enough that some of his crater names are still in use. He also cataloged 1,500 stars, named ten new constellations (seven of which remain official, including Lynx and Sextans), and discovered four comets. When his observatory burned down in 1679 he was nearly seventy and rebuilt it. His second wife Elisabetha was his observing partner and continued his work after his death.

Christiaan Huygens

1629 – 1695

Netherlands

Saturn's rings, Titan

Working with a vastly improved telescope of his own design, Huygens cracked the puzzle Galileo couldn't. In 1655 he showed that Saturn was surrounded by 'a thin flat ring, nowhere touching the body.' That same year he discovered Titan, Saturn's largest moon. He also invented the pendulum clock and made foundational contributions to optics, mathematics, and probability theory.

Charles Messier

1730 – 1817

France

The catalog

Messier was a *comet-hunter*. The catalog of 110 deep-sky objects that bears his name was a list of *things to ignore* — fuzzy patches that could be mistaken for comets. He compiled it as a working tool, not as the curated deep-sky tour it later became. He discovered thirteen comets over his career, but it's the catalog of comet-confusers that made him immortal.

William Herschel

1738 – 1822

Germany / England

Uranus and the deep sky

A musician by training who turned to astronomy in middle age. William Herschel built the largest telescopes of his era and discovered Uranus in 1781 — the first new planet found in recorded history. He went on to find two moons of Uranus and two of Saturn, and to systematically sweep the sky with his sister Caroline, cataloging over 2,500 nebulae and star clusters. He also discovered infrared radiation by accident in 1800, while measuring sunlight through prisms.

Caroline Herschel

1750 – 1848

Germany / England

First paid woman astronomer

William's younger sister, Caroline Herschel was the first woman paid for scientific work — a stipend of £50 a year from King George III. She discovered eight comets and fourteen nebulae in her own right, all while assisting William with his observing programs and grinding mirrors. After William's death she returned to Hanover and continued cataloguing from memory. She received the Gold Medal of the Royal Astronomical Society in 1828 and lived to ninety-seven.

John Herschel
1792 – 1871

England / South Africa

Extended deep-sky cataloging to the southern sky

William's only son. John Herschel was a polymath who could have made his name in mathematics, chemistry, or photography — and did, in all three — before turning to the family business of cataloging the deep sky. From 1834 to 1838 he lived at the Cape of Good Hope and systematically surveyed the southern sky with his own telescope, extending his father's catalog to thousands of objects no one in the Northern Hemisphere had seen. His combined northern and southern catalogs became the basis for the *New General Catalogue*. He also coined the words 'photography,' 'negative,' and 'positive,' and his hypothesis that stellar color indicated temperature was a century ahead of stellar astrophysics.

Friedrich Bessel
1784 – 1846

Prussia / Königsberg

First stellar parallax

For 2,300 years the strongest argument against the heliocentric model was that no one could measure stellar parallax — the apparent shift in a star's position as Earth moves around the Sun. If Earth really moved, the stars must be unimaginably far away. In 1838, Bessel finally measured the parallax of 61 Cygni at 0.314 arcseconds, placing the star about 10.4 light-years away. The unimaginable distance was confirmed.

Maria Mitchell
1818 – 1889

USA (Nantucket / Vassar)

First professional American woman astronomer

Daughter of a Nantucket Quaker family with a rooftop observatory, Maria Mitchell learned the sky alongside her father. On the night of October 1, 1847, she spotted a faint comet that had not been reported. King Frederick VI of Denmark had offered a gold medal for the first new comet discovered with a telescope — Mitchell won it. She became the first woman elected to the American Academy of Arts and Sciences (1848), and in 1865 the first female professor of astronomy in the United States, at the newly founded Vassar College. She trained a generation of women observers and argued, decades before it was popular, that women belonged in science. The crater Mitchell on the Moon is named for her.

Williamina Fleming
1857 – 1911

Scotland / Harvard

Led the Harvard Computers; spotted the Horsehead

She arrived at Harvard as a housekeeper for the observatory director, hired after her husband abandoned her with a young son in Boston. Edward Pickering, frustrated with his male assistants, declared that his Scottish maid could do the work better — and gave her the job. She did. By 1881 she was managing the team of women that would become the Harvard Computers, including the young Cannon, Leavitt, and later Payne. She personally classified over 10,000 stars, developed an early spectral classification system, and in 1888 spotted a dark patch shaped like a horse's head in front of bright nebulosity in Orion — B33, the Horsehead Nebula. She remained the team's leader and most prolific worker until her death.

Annie Jump Cannon

1863 – 1941

USA / Harvard

Stellar classification (OBAFGKM)

One of the Harvard 'Computers' — women employed at the Harvard College Observatory to do the painstaking work of analyzing photographic plates. Cannon classified over 350,000 stars by their spectra and devised the OBAFGKM sequence still in use today (the mnemonic 'Oh Be A Fine Girl/Guy, Kiss Me' is her legacy). She could classify a stellar spectrum in three seconds and was the first woman to receive an honorary doctorate from Oxford.

Henrietta Swan Leavitt

1868 – 1921

USA / Harvard

The cosmic yardstick

Another of the Harvard Computers, Leavitt was given the tedious task of measuring the brightness of variable stars in the Small Magellanic Cloud. In 1912 she noticed a pattern: the longer a Cepheid variable's pulsation period, the brighter its average luminosity. Because all those stars sat at roughly the same distance, she had found a way to use period as a yardstick. Within a decade her relation would let Hubble measure the distance to Andromeda. She died at fifty-three, before the full impact of her work was realized.

Karl Schwarzschild

1873 – 1916

Germany / Russian front

First exact solution to Einstein's equations — black holes

Within months of Einstein publishing the general theory of relativity, Schwarzschild — serving as an artillery officer on the Russian front in World War I — worked out the first exact solution to the field equations: the gravitational field around a non-rotating spherical mass. His solution contained a strange singularity at what we now call the Schwarzschild radius — the event horizon. He had described, mathematically, what we now call a black hole, decades before anyone took the result seriously. He sent the work to Einstein in December 1915 and died of an autoimmune disease contracted at the front a few months later. Every image of a black hole — M87*, Sgr A* — is a portrait of his equation.

Arthur Eddington

1882 – 1944

England (Cambridge)

Confirmed Einstein; stellar interiors

Quaker, conscientious objector, and arguably the foremost astrophysicist of the early 20th century. Eddington organized the 1919 eclipse expedition to Príncipe Island that measured the bending of starlight by the Sun, confirming general relativity and making both Einstein and himself household names overnight. He also worked out the basic physics of stellar interiors — what holds a star up against gravity, how hot its core must be — and wrote popular books that introduced an English-speaking public to relativity and cosmology. Famously asked whether it was true that only three people in the world understood general relativity, he paused and replied: 'I am trying to think who the third person is.'

Cecilia Payne-Gaposchkin

1900 – 1979

England / USA / Harvard

Stars are made of hydrogen

Her 1925 Harvard PhD thesis — *Stellar Atmospheres* — demonstrated through careful spectral analysis that stars are overwhelmingly composed of hydrogen and helium. This contradicted the dogma that stars and Earth had similar composition, and her thesis adviser pressured her to soften her conclusions. She did, calling the result 'almost certainly not real.' Within a few years everyone else realized she had been right all along. Her thesis was later called 'undoubtedly the most brilliant PhD thesis ever written in astronomy.'

Edwin Hubble

1889 – 1953

USA / Mount Wilson

Galaxies and an expanding universe

Working at the 100-inch Hooker telescope on Mount Wilson — then the largest in the world — Hubble identified Cepheid variables in the Andromeda 'nebula' in 1923, applied Leavitt's relation, and showed Andromeda sat at least 900,000 light-years away and entirely outside the Milky Way. (His underestimate was corrected to roughly 2.5 million light-years after Walter Baade's 1952 work on the Cepheid scale.) Either way, the universe was vastly bigger than anyone had thought. Within six years Hubble had shown that distant galaxies were receding at speeds proportional to distance — the universe was expanding. The Hubble Space Telescope is named after him.

George Gamow

1904 – 1968

Ukraine / USA

Predicted the cosmic microwave background

A Russian-born physicist who defected to the West in 1933, Gamow worked out the physics of the very early universe before anyone had observed it. In 1948 he and his students Ralph Alpher and Robert Herman calculated that the Big Bang should have left behind a faint thermal afterglow — a relict radiation field at a few kelvin, filling all of space. The prediction was largely ignored until Penzias and Wilson accidentally detected it in 1964, sixteen years later. Gamow also wrote some of the best popular physics of the 20th century — his *Mr Tompkins* books introduced a generation of readers to relativity and quantum mechanics in the form of dream sequences.

Subrahmanyan Chandrasekhar

1910 – 1995

India / USA (Chicago)

The Chandrasekhar limit; stellar collapse

At nineteen, on a boat from India to Cambridge to take up a scholarship, Chandrasekhar worked out a calculation that would define his career: that a white dwarf star with more than 1.4 solar masses could not support itself against gravity. Above that limit (the Chandrasekhar limit) a star must collapse further — into a neutron star, or beyond. Arthur Eddington, then the king of stellar astrophysics, publicly humiliated him at a 1935 Royal Astronomical Society meeting and refused to accept the result. Chandrasekhar moved to America and quietly built a career; he won the Nobel Prize for the same calculation in 1983. He also edited the *Astrophysical Journal* for nineteen years.

Helen Sawyer Hogg

1905 – 1993

USA / Canada (David Dunlap Observatory)

Variable stars in globular clusters

For sixty years at the David Dunlap Observatory north of Toronto, Helen Sawyer Hogg studied variable stars in globular clusters — work that helped pin down the ages and distances of those ancient stellar systems. She wrote a weekly astronomy column for the *Toronto Star* for thirty years, popularizing astronomy for a generation of Canadians. She was the first woman elected to the Physical Sciences section of the Royal Society of Canada, and asteroid 2917 Sawyer-Hogg is named for her.

Karl Jansky

1905 – 1950

USA (Bell Labs)

Founded radio astronomy

A 25-year-old engineer at Bell Labs, assigned the dull task of investigating sources of static affecting transatlantic radio-telephone service. He built a large rotatable antenna in a New Jersey field and over the course of 1931 identified three sources of noise: nearby thunderstorms, distant thunderstorms, and a third faint hiss whose source moved across the sky on a sidereal day. By 1933 he had traced it to the center of the Milky Way. He had detected, for the first time, electromagnetic radiation from an astronomical source outside the optical band — a whole new window on the universe. Bell Labs declined to follow up. He spent the rest of his short career on other things. The unit of radio flux density is named the jansky.

Jocelyn Bell Burnell

b. 1943

Northern Ireland / UK

Pulsars

As a Cambridge graduate student in 1967, Jocelyn Bell noticed a peculiar repeating signal in the chart-recorder output of a radio telescope: a pulse every 1.337 seconds. She and her supervisor Antony Hewish jokingly called it 'LGM-1' — Little Green Men — before realizing it was a previously unknown type of object: a rapidly rotating neutron star, a pulsar. The 1974 Nobel Prize went to Hewish (and Martin Ryle). It did not go to her. She has since been one of the most graceful figures in modern science, using her platform to advocate for the underrepresented.

Vera Rubin

1928 – 2016

USA

Dark matter

In the 1970s, Vera Rubin and Kent Ford measured the rotation curves of spiral galaxies — how fast different parts spin. The curves were flat in a way that made no sense if galaxies were just stars and gas: there had to be enormous amounts of unseen mass holding them together. Her measurements, repeated across galaxy after galaxy, are what made dark matter undeniable. The Vera C. Rubin Observatory now coming online in Chile is named in her honor.

Carl Sagan

1934 – 1996

USA (Cornell)

Planetary scientist and public voice for astronomy

A working planetary scientist who showed that Venus's surface was infernally hot due to a runaway greenhouse effect, helped plan the Viking, Voyager, and Galileo missions, and proposed organic-chemistry models for Titan's haze. He also became the most effective public voice for astronomy of the 20th century. His 1980 PBS series *Cosmos* reached half a billion viewers worldwide. He designed the Pioneer plaque and chaired the committee that selected the contents of the Voyager Golden Record. The famous 'Pale Blue Dot' image of Earth seen from beyond Neptune was his idea, and his commentary on what it shows — that everyone who ever lived spent their lives on a mote of dust in a sunbeam — remains one of the most-quoted passages in science writing.

Stephen Hawking

1942 – 2018

England (Cambridge)

Black hole thermodynamics

Diagnosed with ALS at twenty-one and given two years to live, Hawking lived another fifty-five — and in the early 1970s worked out one of the most surprising results in 20th-century physics: that black holes are not perfectly black. Quantum effects at the event horizon should cause them to emit a faint thermal radiation, and over enormous timescales they should evaporate. The prediction unified general relativity, quantum mechanics, and thermodynamics, and remains the deepest puzzle in theoretical physics. His 1988 book *A Brief History of Time* sold more than ten million copies. He held Newton's chair at Cambridge for thirty years.

Part 3 — Discovery Stories

Eight longer tales tied to objects you can actually point a telescope at. The supernova that became the Crab Nebula. The proof that Andromeda was a galaxy. The eclipse expedition that confirmed Einstein. The decades-long puzzle of Saturn's rings. A planet found by mathematics. A network of canals on Mars that turned out to be inside an observer's eye. A patient year at a blink comparator that produced Pluto. And the accidental detection of the oldest light in the universe.

The Crab Nebula and the Supernova of 1054

M1 in Taurus · event 1054 CE · rediscovered by Bevis (1731) and Messier (1758)

On the morning of July 4th, 1054, Chinese imperial astronomers recorded a 'guest star' in the constellation we now call Taurus. It was bright enough to be visible in daylight for 23 days and remained a naked-eye object at night for almost two years. Arab and possibly Indigenous American astronomers recorded it as well. Then it faded, and for nearly seven centuries no one knew where it had gone.

In 1731, the English physician and amateur astronomer John Bevis observed a small fuzzy patch in roughly the same part of Taurus and added it to his star atlas. In 1758, Charles Messier rediscovered the same patch while looking for the return of Halley's Comet, and the confusion frustrated him enough that he began compiling his famous catalog of *non-comets* — making the Crab Nebula the first entry, M1, in what would become the most-used list of objects in amateur astronomy.

It was not until the 20th century that the connection was made: the Crab Nebula is the still-expanding wreckage of the 1054 supernova. At its center sits a pulsar — a rapidly spinning neutron star, the collapsed remnant of the original star — that flashes thirty times per second. When you find M1 in your eyepiece, you are looking at a star whose explosion lit up European skies twelve years before the Norman Conquest, and at the corpse that is still alive enough to keep a clock.

Andromeda Becomes a Galaxy

M31 in Andromeda · 1924 · Edwin Hubble

In 1920, the National Academy of Sciences hosted what became known as the Great Debate: Harlow Shapley arguing that the spiral 'nebulae' like M31 were small nearby objects inside the Milky Way; Heber Curtis arguing they were 'island universes' — entirely separate galaxies — at unimaginable distances. The debate ended unresolved. Both sides had data. Neither side could prove their case.

Three years later, at the 100-inch Hooker telescope on Mount Wilson, Edwin Hubble found a Cepheid variable star on a plate of M31. Cepheids were special: thanks to Henrietta Leavitt's period-luminosity relation, their pulsation period revealed their true brightness, and comparing true brightness to apparent brightness gave you the distance.

Hubble did the calculation. The Cepheid sat about 900,000 light-years away — far enough that M31 had to be utterly outside the Milky Way. (Modern measurements put it at 2.5 million light-years, after Walter Baade's 1952 correction to the Cepheid scale, but even Hubble's underestimate was enough to settle the argument.) M31 wasn't a nebula at all. It was another *galaxy*, a vast spiral of hundreds of billions of stars, the nearest of a population of similar objects we now know extends as far as our telescopes can see.

Curtis had been right, but it took Hubble's patient work over many months — tracking that first Cepheid and then a dozen more on plate after plate — to settle an argument that went back to Kant's speculation about 'island universes' in the 1750s. When you find the smudge of M31 in your finder tonight, you're looking at the place in the sky where the universe quietly became a thousand times bigger than anyone had imagined.

The Eclipse of 1919: Einstein Confirmed

The Sun · 29 May 1919 · Arthur Eddington, Príncipe Island

In 1916, Einstein's newly completed general theory of relativity made a sharp, testable prediction: a beam of starlight passing close to the Sun's edge should be deflected by 1.75 arcseconds — about twice the deflection predicted by Newton's gravity treated naively. The only way to test it was to photograph stars near the Sun's disk, and the only way to do that was during a total solar eclipse.

The eclipse of May 29, 1919 was the moment. The path of totality cut across the Atlantic. Two British expeditions were sent: Andrew Crommelin to the Brazilian town of Sobral, and Arthur Eddington — a Quaker pacifist who had spent the war refusing to fight a man whose theory he was now travelling to test — to the tiny island of Príncipe off West Africa.

On the morning of the eclipse, Príncipe was rained out. The clouds began to thin fifteen minutes before totality. Eddington made his photographic exposures behind thinning haze and saved sixteen plates, of which only two showed enough stars to measure. He spent the next days at a comparator, measuring tiny shifts in stellar positions between his eclipse plates and reference plates of the same star field taken months earlier. The shift was there. It matched Einstein's prediction, not Newton's.

The result was announced at a joint meeting of the Royal Society and Royal Astronomical Society in London on November 6, 1919. The chair, J.J. Thomson, called general relativity 'one of the greatest achievements in the history of human thought.' The next morning the *Times* of London ran the headline 'Revolution in Science — New Theory of the Universe — Newtonian Ideas Overthrown.' Einstein, almost unknown outside physics six months earlier, became the most famous scientist in the world overnight.

Modern reanalyses suggest Eddington's 1919 data alone were marginal — the error bars were larger than the announcement let on. But the 1922 eclipse, the 1929 eclipse, and every more sensitive test since have confirmed the deflection cleanly. The Sun really does bend starlight by exactly the amount Einstein said it would. Every GPS fix on your phone runs on the same physics.

Saturn's Rings: A Mystery from Galileo to Huygens

Saturn · 1610 – 1655 · Galileo Galilei, Christiaan Huygens

When Galileo turned his telescope on Saturn in 1610, what he saw confused him. The planet seemed to have something attached to either side. He couldn't resolve what it was — his optics weren't sharp enough — and after months of effort he announced that Saturn was 'triple-bodied,' as though it had two small companions on either side.

Then, two years later, the companions vanished. Galileo wrote, baffled: 'Has Saturn devoured his children?' Saturn had simply rotated so its rings were edge-on and invisible from Earth — a phenomenon that recurs every fifteen years. But Galileo never solved the puzzle, and he died in 1642 without knowing what he had seen.

The mystery sat unanswered for forty-five years. Then in 1655, the young Dutch astronomer Christiaan Huygens — using a telescope of his own design, longer and sharper than anything Galileo had — looked again. He discovered Saturn's largest moon, Titan, that March, and within months had worked out the puzzle. He couldn't publish the answer right away (the convention of the day was to lock priority claims with anagrams while the work was checked) but by 1659 he set it out plainly in *Systema Saturnium*: Saturn was surrounded by 'a thin flat ring, nowhere touching the body.'

It took human observers nearly half a century, working with primitive optics, to understand what is now the most recognizable sight in the solar system. The next time you look at Saturn's rings through your scope and find them obvious, that obviousness is purchased — it cost two of the best minds in history a generation of work.

Neptune by Mathematics

Neptune · 1846 · Le Verrier, Adams, Galle

Uranus, discovered by William Herschel in 1781, didn't quite behave. As decades passed and astronomers improved their orbital predictions, the planet kept drifting off the predicted path. Something was tugging on it.

In the 1840s, two mathematicians independently took on the problem of finding the perturber. John Couch Adams in England and Urbain Le Verrier in France both used Newtonian gravity to work backward from Uranus's anomalies and predict where the unseen planet must be. Adams's calculations had been circulating privately in England since 1845, but he never published a formal prediction. Le Verrier's predictions were sharper and arrived at the French Academy first, on August 31, 1846. Frustrated by lack of follow-up at home, Le Verrier sent his prediction in a letter to Johann Galle at the Berlin Observatory.

Galle read the letter on the evening of September 23rd, 1846. Working with his student Heinrich d'Arrest, he turned the telescope to the predicted spot. Neptune was there, less than a degree from where Le Verrier said it would be. Within an hour of opening the letter, the planet was confirmed. Adams himself publicly acknowledged Le Verrier's priority within weeks.

It remains one of the most stunning vindications of theoretical science in history: a planet found not by sweeping the sky, but by paper and pen. When you find Neptune as a faint blue-grey dot in your eyepiece, you're finding a world that was first seen by mathematics.

The Canals of Mars

Mars · 1877 – 1965 · Schiaparelli, Lowell, Antoniadi, Mariner 4

In 1877, during a particularly favourable opposition of Mars, the Italian astronomer Giovanni Schiaparelli mapped a network of fine linear features crossing the planet. He called them *canali* — Italian for 'channels' or 'grooves,' with no implication of artificial construction. The word was translated into English as 'canals,' and a century of trouble followed.

The man who ran furthest with it was Percival Lowell. In 1894 the wealthy Bostonian built his own observatory on a Flagstaff mesa, chosen specifically for the steadiest air he could find in the United States, and turned a 24-inch refractor on Mars night after night. Over the next two decades he produced detailed maps of an elaborate canal network — hundreds of straight lines, junctions, 'oases' — and argued, in three popular books, that the canals were an irrigation system built by a dying civilization to move meltwater from the polar caps.

Lowell was not alone in seeing canals. Other careful observers reported them too, though no two maps quite agreed. Visual observation at the limit of telescope resolution is a strange thing: the human eye and brain are exquisite pattern-recognizers, and at the edge of perception they will connect ambiguous smudges into the shapes the observer expects. Lowell expected canals, and Lowell saw canals.

By 1909, the Greek-French astronomer Eugène Antoniadi was looking at Mars through a much larger telescope in steadier seeing at the Meudon Observatory near Paris. He saw the surface sharper than anyone before him — and the canals dissolved into irregular dapples and patches with no linear structure at all. The case was effectively closed among serious astronomers within a decade. But the canals lived on in popular imagination, in science fiction, and in Lowell's own books, until NASA's Mariner 4 flew past Mars in July 1965 and sent back the first close-up photographs of an arid, cratered world with no canals of any kind.

The Mars canals are worth keeping in mind at the eyepiece. The sky rewards patience — but it also rewards humility. The most experienced observer can stare at the same patch of light for a decade and see something that isn't there.

The Long Search for Pluto

Pluto · 1930 · Clyde Tombaugh

Percival Lowell believed there had to be a Planet X beyond Neptune. Until his death in 1916 he searched obsessively for it, using mathematical predictions based on supposed irregularities in Neptune's orbit. He found nothing.

Thirteen years after Lowell's death, the Lowell Observatory hired a 23-year-old farm boy from Kansas named Clyde Tombaugh. Tombaugh had no formal astronomy training, but he had built his own telescopes from farm-equipment parts and his sketches of Mars and Jupiter were good enough to get him the job. The task: comb through photographic plates of the night sky, taken a few days apart, looking for any point of light that had moved.

He used a blink comparator — a device that flipped rapidly between two plates so that anything that moved appeared to jump. Each plate held hundreds of thousands of stars. He spent a year on it.

On February 18th, 1930, comparing two plates of the Gemini region taken six days apart in late January, Tombaugh spotted a tiny dot that moved exactly as a distant planet should. Pluto was announced six weeks later, on what would have been Lowell's 75th birthday. Tombaugh died in 1997, just shy of ninety-one. He did not live to see his planet demoted to a dwarf in 2006, nor the launch of NASA's New Horizons that same year — but his widow approved sending a portion of his ashes aboard the spacecraft, which flew past Pluto in 2015 carrying its discoverer home.

The Cosmic Microwave Background

The whole sky · 1964 · Arno Penzias and Robert Wilson

In 1964, two radio astronomers at Bell Labs in Holmdel, New Jersey, were trying to use a sensitive horn antenna originally built for satellite communications to do radio astronomy. They had a problem: a persistent, faint background hiss in every direction, no matter where they pointed the antenna.

They cleaned the antenna. They checked the wiring. Pigeons had been nesting inside the horn — Penzias and Wilson cleaned out what they politely called 'a white dielectric material' (pigeon droppings). The hiss remained. It was the same at every time of day, in every direction in the sky, in every season. It corresponded to a temperature of about 3 kelvin, just above absolute zero.

A few miles away, at Princeton, Robert Dicke and his team were *predicting* exactly such a signal: the faint, cooled-down afterglow of the Big Bang, redshifted from when the universe became transparent about 380,000 years after it began. When the Princeton group heard about the Bell Labs signal, Dicke is said to have hung up the phone and told his team, 'Well boys, we've been scooped.'

Penzias and Wilson hadn't been looking for the Big Bang. They had detected it by accident, trying to make their antenna work properly. They received the 1978 Nobel Prize in Physics. The cosmic microwave background, the faint hiss they couldn't get rid of, is now the most precisely measured signal in cosmology — the oldest light in the universe, leftover heat from when the universe was a hot bath of plasma. You cannot see it with your eyes. But it is everywhere around you, all the time.

Part 4 — What We Inherited

Astronomy didn't stay in the sky. The work in this guide quietly shaped the timekeeping, language, and technology you use every day. The hour on your watch, the names of the days, the date of Easter, even the GPS in your phone — all of it is sky-work hiding in plain sight. A few of the threads.

The 24-hour day and the 60-minute hour

Babylonian astronomers, working in a sexagesimal (base-60) number system, divided the full day into 12 'beru' (double-hours), each equal to two of our modern hours. The 60-minute hour, the 60-second minute, and the 360 degrees of a circle all descend from the same Mesopotamian arithmetic. Every time you set an alarm, you are using a counting system that predates the wheel.

The seven-day week

There is no obvious astronomical reason for a seven-day week — until you remember the seven naked-eye 'wandering stars' that ancient sky-watchers tracked: the Sun, the Moon, and the five visible planets (Mercury, Venus, Mars, Jupiter, Saturn). Each got a day. In English, three are still transparent: **Sunday** is the Sun's day, **Monday** is the Moon's, **Saturday** is Saturn's. The other four are planetary too — but with a detour through Norse mythology. When the Germanic peoples adopted the Roman week they swapped in their own gods, matching each to the Roman one whose character was closest: **Tuesday** is Tiw's day — Tyr, the war god, stood in for Mars (French *Mardi*). **Wednesday** is Woden's day — Odin, the wandering wisdom god, stood in for Mercury (*Mercredi*). **Thursday** is Thor's day — the thunder god with his hammer, paired naturally with thunder-king Jupiter / Jove (*Jeudi*). **Friday** is Frigg's day — the love goddess, paired with Venus (*Vendredi*). The week you live by is a fossil of pre-telescopic astronomy, with one detour through a Norse longhouse.

The calendar

Julius Caesar's 365.25-day calendar, devised in 46 BCE by the Greek astronomer Sosigenes, fit the solar year well enough for sixteen centuries — but the year is actually 365.2422 days, and the drift accumulated. By 1582 the calendar was ten days out of step with the equinoxes. Pope Gregory XIII's reform dropped those ten days (people went to bed on October 4th and woke up on October 15th) and tightened the leap-year rule. Every leap year is an astronomer's correction.

GPS requires Einstein

The satellites that tell your phone where you are orbit at 20,000 km, moving fast enough that special relativity slows their clocks, and high enough in Earth's gravity that general relativity speeds them up. Without both corrections — both consequences of theoretical astronomy from the early 20th century — GPS positions would drift by about 10 kilometres a day. Every map app on Earth is quietly running Einstein in the background.

Time zones

For most of human history, every town set its clocks by local noon. This worked until trains began moving people faster than the sun. In 1884 an international conference in Washington established Greenwich, England as the world's prime meridian — chosen because the Royal Observatory there had been the de facto reference for astronomical positions and navigation for two centuries. The 24 standard time zones we use today were built on that foundation in the decades that followed. Your phone's clock still defers to it.

Words from the planets

Jovial people are born under Jupiter (Jove). *Mercurial* ones change like Mercury. *Saturnine* people are heavy and brooding, the way Saturn was thought to be slow. *Martial* matters belong to Mars, god of war. A *lunatic* was someone affected by the Moon. *Disaster* means, literally, 'bad star.' English carries astronomy in its everyday vocabulary, unnoticed.

Knowing how old anything is

Before astronomy got serious about distances, no one knew how old the Earth was within a factor of a thousand. The work in this guide — Bessel measuring stellar parallax, Hubble measuring galactic distances, Penzias and Wilson measuring the cooled glow of the Big Bang — gave us the cosmic calendar. Earth is 4.6 billion years old. The universe is 13.8 billion. The light from M31 in your finder tonight left around the time our earliest ancestors in the genus *Homo* were chipping the first stone tools on the African savanna. None of those numbers existed two centuries ago.

Easter and the computus

The Christian church needed to know the date of Easter, which depends on the first full moon after the spring equinox — both astronomical events. For roughly a thousand years, calculating Easter (the *computus*) was the most demanding mathematical work in Europe. It kept monasteries doing astronomy when little other science was being done, and it preserved the techniques that would become the foundation of European mathematics. Even Easter Sunday is, ultimately, an astronomical date.

A note to close

Astronomy is unusual among the sciences in that almost everything you read about in this guide is still happening. The Crab pulsar is still spinning. Andromeda is still approaching the Milky Way at 110 kilometres per second. Saturn's rings are slowly raining down onto the planet and will be gone in perhaps a few hundred million years. The cosmic microwave background is still arriving, photon by photon, at every square centimetre of your skin.

And the work continues. The Vera C. Rubin Observatory is starting its sky survey. The James Webb Space Telescope is sending back images of the earliest galaxies. Somewhere tonight, a graduate student is staring at a plot of data and noticing something nobody has noticed before. The names in this guide were the same kind of person, doing the same kind of work, in their own time.

When you set up tonight, you are joining a line of human beings that goes back four thousand years. *Carpe noctem* — and find more guides, conditions, and tools at **whatsuptonight.ca**.