SAMPLE

Solar System Missions: Solar Orbiter

Close to the Sun

Aira Astralis

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Introduction

The Sun has a far side that no telescope on Earth has ever seen properly: its poles. Every eye humanity has ever trained on the star, from the observatories of the plains to the spacecraft of the solar age, has looked at it from roughly the plane in which the planets circle, the ecliptic, a ring around the Sun's middle; the poles themselves, the caps of the great magnetic dynamo that drives every sunspot cycle and every storm of the space-weather era, have stayed tilted out of clear view, seen only glancingly, their workings guessed at from the wobbling edge.

Solar Orbiter is the spacecraft built to close that gap: a joint European and

American probe, launched in 2020, that has been lowering itself into an orbit closer to the Sun than any imaging spacecraft before it and, more remarkably, tilting that orbit out of the plane of the planets, so that, for the first time since the species began flying cameras, an observatory looks down on the Sun's crown and up under its southern cap.

The mission's brief is the Sun's own machinery, and the book that follows is its account for the general reader. The chapters set out the problem the poles pose, the observatory built to face it, and the long spiral that carried it sunward and out of the plane; they then widen the frame to the craft's family of watchers and its diving sister, its first light, the young wind it tasted, the storms it read at the source, and the polar campaign that is the mission's whole errand; and they close with the open observatory's harvest, the crown's visitors from the comet roads, and the first full look at the star's crown. The account asks no equations of the reader, reports the mission's instruments and ancestors by their work, and keeps the scale honest at every step; and the reader who finishes it will know both what the poles have already said and why the field's next decade of questions will be asked in the orbiter's accent.

The stakes deserve a sentence before the technical account begins. The Sun's eleven-year rhythm, the magnetic cycle whose poles trade places every cycle's turn, is the clock of space weather: it sets the storm count, the aurora's latitude, the satellite operator's year. That cycle's engine is in the polar regions Solar Orbiter now photographs, and the forecasts the century will need, for grids and satellites and astronauts, run through the polar fields whose birth, drift, and reversal the spacecraft was sent to watch. The mission is, in that sense, the observatory of the space-weather century, and the reader who follows it will follow the subject every forecaster of the solar system's weather is now watching.

A word on scale before the account starts, because the mission's numbers are

easy to say and hard to feel. The Sun is a hundred and fifty million kilometers away, and Solar Orbiter's closest passes cut that to roughly forty million, a distance that sounds like a small adjustment until the reader pictures the light: thirteen suns' worth of brilliance, a wall face hot enough to bake ceramics, a star that fills the imagers' fields of view the way a city fills a train window. The spacecraft crosses that closeness in hours, months between passes, the whole mission a long patience punctuated by brief brilliance, and the chapters ahead follow both the patience and the brilliance: the flybys that built the orbit, the passes that took the images, the tilt that opened the caps, each step small in words, enormous in kilometers and in heat.

Chapter 1: The Poles Nobody Could See

The Sun's problem, from the point of view of an Earth-bound observer, is geometry. The star's rotation axis is tilted a bit more than seven degrees relative to the plane of the planets, so its poles lean slightly toward and away from the ecliptic over the course of the year; but the lean is small, and an observer in the plane sees the poles only edge-on, foreshortened, badly lit for charting, the way a globe viewed from its own equator shows its caps as thin crescents. Half a century of solar observatories, ground-based and orbital, has therefore charted the Sun's face and middle latitudes in exquisite detail while its crown and southern cap stayed the star's least-photographed real estate, known mainly from the wobbling, from the rare passes of out-of-plane probes without cameras, and from the inferences of the modelers, who needed the polar fields to make the cycle work and could not see them.

Why the poles matter is the chapter's real subject, and the answer is the magnetic cycle. The Sun is a dynamo: its rotation, its convection, and its shifting bands of surface flow generate magnetic fields that migrate and concentrate, and the cycle's pattern, the sunspots' eleven-year heartbeat, the fields' wholesale reversal every cycle's turn, is organized at the poles, where the star's global field lives between the spot latitudes' churning. The polar fields are the reservoir and the seed of the next cycle: the mid-latitude spots' flux drifts poleward, cancels the old polarity, builds the new, and the cycle turns over; the modelers who reconstruct this engine, the dynamo theorists, have worked for decades with a polar field they could only infer, and every cycle's surprises, the deep minimum that fooled the forecasters, the lopsided maximum that followed, have traced back to polar behavior nobody had watched. The poles are the Sun's memory of its own cycle, and the memory had never been read in the act.

The space age's first polar answer was a probe without a camera. Ulysses, the joint European-American spacecraft of the 1990s, took a Jupiter gravity assist to leave the ecliptic and flew over the Sun's poles repeatedly, measuring everything its instruments could sense: the wind's speed, the field's strength, the particle populations. Ulysses proved the poles' wind was fast and steady, rewrote the textbook's picture of the three-dimensional heliosphere, and left the solar physicists with a hunger it could not feed: it carried no imaging, and the polar fields and flows it measured could not be connected to the structures that produced them, the coronal holes, the bright loops, the jets and fires whose polar forms the modelers argued about from secondhand evidence. The lesson of Ulysses, absorbed into every mission-planning discussion since, was plain: the poles needed a camera, close, and out of the plane.

The chapter's closing is the mission's birth certificate: the requirement that grew from all of this, formulated in the European space agency's science planning of the 2000s as a mission to image the Sun's poles from inside Mercury's orbit, tilted out of the ecliptic, in coordination with whatever in-situ probes the era could provide. The requirement became a spacecraft, the spacecraft became a launch, and the account that follows is its story: the design that survived the heat, the orbit that tilts, the images that have already redrawn the star's fine structure, and the polar campaigns that are, as this book is written, giving the species its first proper look at the crown of its own star.

The Sun's tilt deserves one more paragraph, because the geometry is subtler than a simple cap. The star's equator leans about seven degrees out of the planets' plane, so the poles do nod slightly toward the Earth over the year; a patient observer can see each cap a little better in one season, a little worse in the next. The nod, over the history of solar observation, was enough to count the sunspot migration and infer the polar fields' reversal, and it fed the modelers their rough polar data for decades; but the nod is a squint, not a view, and the difference between squinting at a cap and photographing it is the difference this whole mission exists to make.

The reader who wants the contrast in one image can picture a globe on a desk: from the desk's plane, the globe's caps are visible only as thin arcs at the limb, while a camera lifted a hand's width above the plane sees the cap as a cap, whole and chartable, the lift Solar Orbiter spends a decade buying.

The century's forecast failures deserve a paragraph, because they are the practical stake of the polar blind spot. The space age's solar cycles have twice humbled its forecasters: a deep quiet minimum arrived when the consensus expected a moderate cycle, and the following maximum ran lopsided, strong in one hemisphere of the star and weak in the other, the pattern the standard models had not drawn. Both surprises traced to polar behavior, the fields' strength and the caps' asymmetries, the data the forecasters lacked because the crown was unread; and the forecasters' response, in the era's reports, was a standing call for exactly the polar observations this mission now makes. The reader should hold the connection with a light grip but a real one: the forecasts that protect satellites and grids fail at the poles, and the observatory that reads the poles is the forecast's missing eye, the mission's quiet service to the century's infrastructure, delivered from the crown of the star.

The chapter should close with the poles' first portraits, because the eclipse corona was drawing them for a century before any craft could climb to see. At each total eclipse the corona stands revealed, and its shape has always been

the cycle's silhouette: in the quiet years the crown stretches long equatorial streamers and leaves the poles nearly bare, the corona drawn as a flattened belt; in the active years it rounds into a bristling sphere, every latitude dressed; and the eclipse watchers, sketching and photographing century after century, were drawing the poles' magnetic biography without knowing it, the corona's bare poles being the open field lines the wind pours from, the dressed poles the closed cages of the maximum.

The reader should hold the lineage's irony: the poles that no telescope could face were sketched into every eclipse drawing, their emptiness and fullness the first record of the cycle, and the orbiter's polar cameras, a century later, are the instruments that can finally check what the silhouettes promised, the eclipse era's unfinished portrait at last receiving its sitting.

End of free sample. The full book is available at putrabooks.github.io

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.