SAMPLE

Great Observatories: SOFIA

The Flying Infrared Telescope

Aira Astralis

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Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

The subject of this book is an airplane. Not a city, though the name is shared with a European capital; not a person, though the name is a common one; the subject is the Stratospheric Observatory for Infrared Astronomy, an observatory named SOFIA, a converted Boeing 747 that carried a telescope bigger than the one in most ground observatories to the edge of the atmosphere, opened a hole in its own fuselage in flight, and watched the cold universe for more than a decade. The namesakes deserve a sentence and no more: the city is a fine place, the name a fine name, and neither is treated here beyond this note, because the book's business is the flying observatory.

SOFIA belonged to the Great Observatories' extended family in spirit, though it lived in a different world from its spaceborne cousins: lower than the telescopes in orbit, far above the telescopes on the ground, mobile in a way neither could match. From its working altitudes, twelve and fourteen kilometers up, it rose above almost all of the water vapor that soaks up the infrared light arriving from space, and in that infrared the universe looks nothing like the familiar sky. Star-forming clouds glow through their own dust. Cold molecules write their signatures in fine bright lines. Warm dust traces magnetic fields across whole galaxies. Nearly all of it is invisible from the ground, and much of it, in the far infrared where SOFIA worked best, was invisible even from a high mountain.

This book tells the story of that observatory from its physics to its retirement: why infrared light is blocked by the very air that makes astronomy possible, how a generation of stubborn airborne astronomers proved a jet could do observatory work, what the aircraft and its German-built telescope actually were, how a night of observing worked at eight hundred kilometers per hour, what the mission found from helium hydride to water on the sunlit Moon, and why it flew its last science flight in 2022. The subject rewards the telling: SOFIA is the best argument ever built that an observatory does not need a mountain or an orbit, only a runway and a reason.

A note on how to read what follows. The fourteen chapters run in the order a visitor to the mission would have experienced it: the physics that made the machine necessary, the machine itself, the work of a flying night, the science the nights produced, and the meaning of the whole thing now that the flying has stopped. The reader needs no mathematics beyond a willingness to picture a wavelength and an altitude, and every number that matters is given in words as well as digits, because the subject is a machine and its sky, not a course.

The chapters are also self-contained enough to be read out of order, and the reader who cares most about the discoveries, the fun facts, or the mission's endgame can jump there first; the book has been built so that each of those doors opens onto the same machine, described enough times, from enough angles, that by the last page the reader will know the flying observatory the way its own crews did: as a place one went to work, at altitude, above the weather, in the service of the coldest light there is.

Chapter 1: The Discovery of SOFIA

The story begins with a nuisance that every astronomer knows: the atmosphere that makes life possible makes infrared astronomy nearly impossible. Infrared light, the radiation of warm and cold things, arrives at

Earth in generous amounts, but the water vapor in the lower atmosphere absorbs most of it on the way down. The narrow gaps where the light gets through, the infrared windows, are few and shallow from sea level, and the water thins only gradually with altitude. A mountain site helps; the high, dry desert peaks that host the great modern observatories sit under perhaps half the water over a sea-level site, still far too much for the far infrared, where the coldest and most interesting radiation lives.

The astronomers who wanted that light faced a choice with three doors: leave the atmosphere entirely, as the space telescopes do; lift a telescope above the bulk of the water with a balloon; or fly one through the stratosphere, where an aircraft can carry a serious telescope, a full crew, and the ability to point it anywhere on Earth.

The aircraft door was opened by Gerard Kuiper, the Dutch-born astronomer who had already discovered the moons Miranda, at Uranus, and Nereid, at Neptune, and who had a habit of simply trying things. In the late 1960s Kuiper strapped a twelve-inch telescope to the side of a small business jet and observed from above the clouds, proving that a stable platform for astronomy could be built out of an ordinary aircraft. NASA's program followed his lead through a succession of larger machines, and the concept matured into the Kuiper Airborne Observatory, a military transport jet, the C-141 Starlifter, carrying a telescope just under a meter across.

From 1975 through 1995 the Kuiper flew out of NASA's Ames center in California, and the discoveries it returned made the case for airborne astronomy more strongly than any report could. In 1977, watching a star pass behind the planet Uranus from the Kuiper's cabin, astronomers saw the star blink off and on five times before and after the planet itself, and discovered that Uranus has rings, the first rings ever found beyond Saturn. In 1988 the same technique, applied to Pluto from the same aircraft, revealed that Pluto has an atmosphere. A converted airliner had discovered a planetary ring system and a dwarf planet's air.

By the 1980s the infrared astronomers had drawn the obvious moral: the concept worked, the platform was limited, and a bigger telescope in a bigger aircraft would open the far infrared systematically rather than by raid. The limiting factor was never the aircraft; the Kuiper's telescope was a third the

size of a serious infrared instrument, and the jet's altitude, in the low stratosphere, left too much water below the wrong way round, still too much water above. The dream specification was set early: a telescope of two and a half meters, flown at twelve and fourteen kilometers, on an airframe large enough to carry it, its instruments, and a working observatory crew.

The aircraft that fit the specification was the Boeing 747SP, the short-body, long-range version of the classic jumbo, and one in particular: an airliner delivered to Pan American in 1977, christened Clipper Lindbergh, flown two decades for Pan Am and United, and retired to the desert in the mid-1990s, exactly when the program went looking for a suitable donor.

The plan that became SOFIA was drafted between the American and German space agencies, NASA taking the aircraft, the modifications, and the operations, the German center DLR building the telescope itself, the largest German astronomical instrument sent aloft to that date. The partnership divided the observatory in a fitting way for a machine whose very name was the word for wisdom: the United States supplied the wings, Germany the eye. The decades between the contract and the first light were long ones, and the chapter will not pretend otherwise. The airframe was gutted and rebuilt, the telescope designed, cast, polished, and mounted behind a pressure bulkhead that keeps the cabin livable while the telescope sits in open stratospheric air.

The program endured budget reviews that proposed its cancellation more than once before it had observed anything at all, and the aircraft itself, aging by airliner standards, kept its engineers as busy as its scientists. In May 2010, in the sky above California, the observatory opened its cavity door in flight for the first time with an instrument behind the telescope, and SOFIA saw its first star: Jupiter, in the infrared, from a hole in the side of a 747. The discovery that matters in this chapter is the program's own: that the thirty-year-old idea of an airborne observatory could be rebuilt into something a hundred times more capable, and that the patient, unglamorous engineering of a decade of assembly could deliver, intact, the concept its inventors had specified.

The chapter's discovery story also has a technological strand the telescope's history should not lose: the decades of airborne astronomy before SOFIA were a working apprenticeship in every part of the discipline. The crews of the earlier aircraft learned to schedule astronomy as aeronautics, planning legs of flight where an observer's integration time met a pilot's fuel margin; the instrument builders of the smaller jets learned cryogenics that could survive a cabin, detectors that could ride a fuselage's vibration, and pointing systems that could hold a target while the platform itself turned; and the program managers learned, in the hard currency of cancelled projects and near-misses,

that a flying observatory is funded the way an airline is funded, flight by flight, forever, which is a different bargain than a spacecraft's single great purchase.

Every one of those lessons was embodied in the specification the German and American agencies signed: the telescope large enough for real sensitivity, the aircraft large enough for a real observatory's crew and instruments, and the partnership structured so that the long development, which everyone knew would outlast several budget cycles, had two governments' weight behind it. The reader should notice that the aircraft that fit the specification was a used one, and that the choice was deliberate: the program bought an airliner mid-life rather than new because the airframe's remaining hours were the mission's whole expected life, a twenty-year instrument built from a twenty-year-old jet, and the arithmetic of that choice, hours remaining against science planned, is the quiet foundation of everything the later chapters describe.

The discovery of SOFIA, in the fullest sense, is thus a discovery about how observatories get built at all: not by one heroic design but by an inheritance of working methods, a lucky find in the desert, and a partnership patient enough to carry a thirty-year-old idea to first light.

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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.