Sharpening the Focus

Adaptive optics was first proposed as a way to improve astronomical measurements, but later it transformed into a tool for ophthalmology and beyond.

1953: Compensating for turbulence

Soon after the development of telescopes came the realization that atmospheric turbulence diminishes the quality of observations. Monitoring the sky from the highest mountaintops would improve clarity, as Sir Isaac Newton once suggested, but even that had limits. To tackle the turbulence issue, astronomer Horace Babcock first proposed the idea for adaptive optics in his *Publications of the Astronomical Society of the Pacific* paper “The possibility of compensating astronomical seeing.” In it, he laid out a theoretical scheme for continuous compensation of wavefront aberrations.

1970s: Air Force interest

The US military drove considerable effort in broadening the scope of adaptive-optics technology, focusing on development of missile defense systems and laser weapons. This yielded full wavefront compensation for white-light imaging and the first deformable-mirror experiments on real telescopes in 1970s. In 1982, the US Air Force achieved the world’s first operational adaptive-optics system, called the Compensated Imaging System, at the Maui Optical Station in Hawaii.

1982: Waves in ophthalmology

Also in 1982, adaptive optics entered the field of ophthalmology, in a conference presentation by Josef F. Bille of Heidelberg University, Germany. Soon, the wavefront-shaping technology made its way into laser-assisted in situ keratomileusis, or LASIK, surgery, enabling “custom” procedures by measuring individual aberration patterns of patients. Other ophthalmic practices also started using adaptive optics to take high-quality images of the retina.
Aiding Telescopes and Microscopes

In recent years, adaptive optics has enabled a range of new scientific findings, even as the technique itself has moved forward.

2020: Imaging star formation
Adaptive optics for ground-based telescopes has continued to improve—even in the era of space telescopes. This has led to the first wide-field near-infrared adaptive-optics images of the Carina Nebula’s western wall, a huge dust cloud near a star-forming region. With the help of adaptive optics, researchers increased the image resolution tenfold, revealing how massive young stars affect their surroundings and influence star and planet formation.

2020: All-photonic wavefront sensor
Adaptive-optics systems need wavefront sensors to gather necessary phase and intensity information from a beam of light, but the sensors come with their own challenges. In 2020, researchers in Australia developed a new type of wavefront sensor based on an optical-fiber technology called a “photonic lantern,” as well as artificial-intelligence algorithms. The new sensor can help astronomers detect extrasolar planets and characterize their physical properties.

2021: Cascading modulators
Scientists first used adaptive optics in microscopy in 1999 for tip–tilt correction. Since then, some systems have employed active, shape-shifting elements such as deformable mirrors or liquid-crystal spatial light modulators to correct for aberrations. In 2021, researchers in Germany developed a module composed of two deformable phase plates, enabling direct integration into existing microscopes.

Satellites as guides: At some of today’s ground-based telescopes, astronomers send a laser beam from the ground to fire up sodium atoms in the middle atmosphere, creating a guidestar—an artificial star used as a baseline to correct atmospheric distortion. To improve on the system, a number of astronomers, including Nobel laureate John C. Mather of NASA, have proposed making guidestars from laser-equipped orbiting satellites instead—something that’s closer to real stars. It’s one example of how adaptive optics, first proposed nearly 70 years ago, hasn’t stopped moving forward ever since.

For references and further resources, go online: optica-opn.org/then-now/adaptive-optics.


