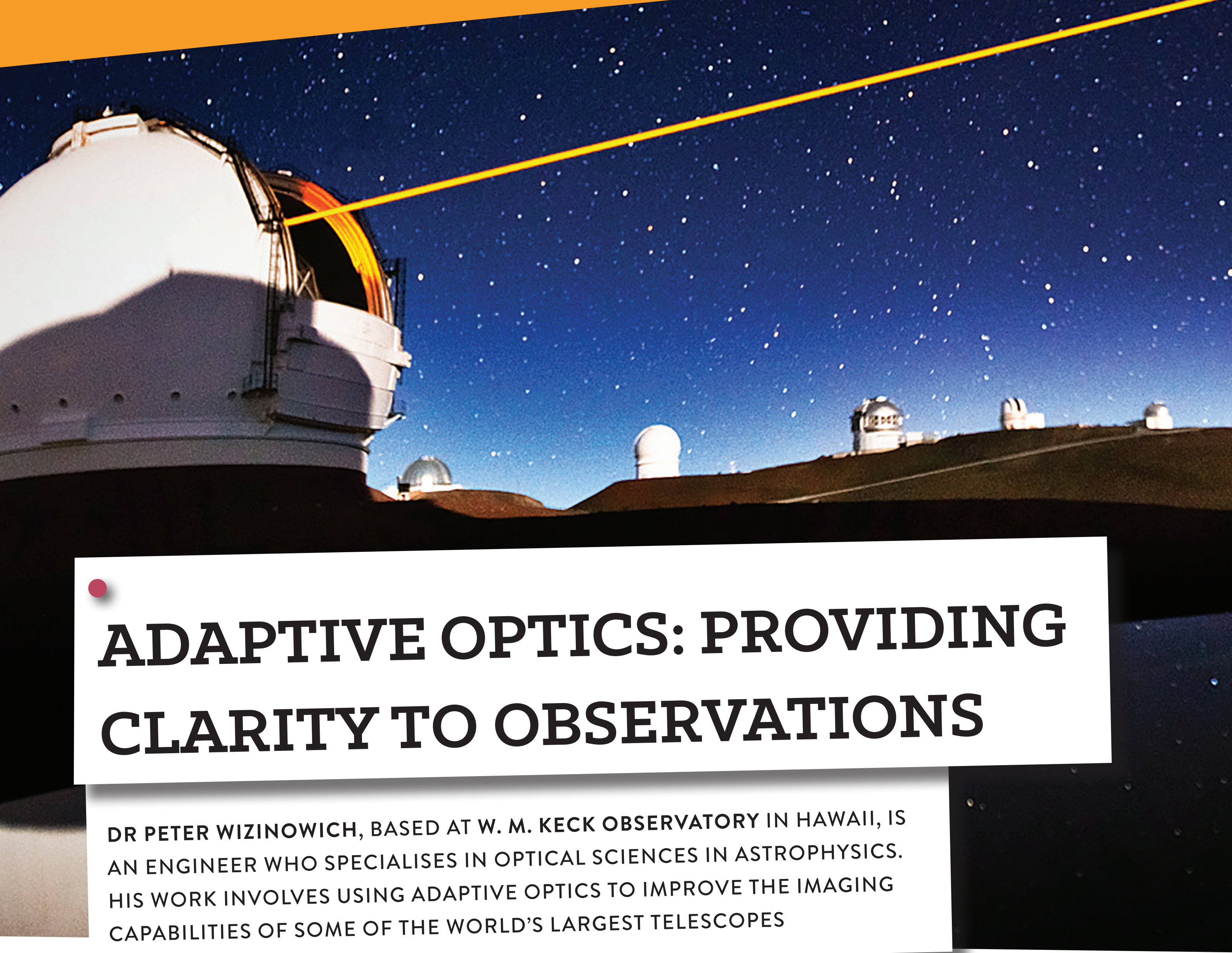


ADAPTIVE OPTICS: PROVIDING CLARITY TO OBSERVATIONS

DR PETER WIZINOWICH, BASED AT **W. M. KECK OBSERVATORY** IN HAWAII, IS AN ENGINEER WHO SPECIALISES IN OPTICAL SCIENCES IN ASTROPHYSICS. HIS WORK INVOLVES USING ADAPTIVE OPTICS TO IMPROVE THE IMAGING CAPABILITIES OF SOME OF THE WORLD'S LARGEST TELESCOPES

In 1608, Dutch eyeglass maker Hans Lippershey patented the world's first telescope (although there is some debate concerning whether he stole the idea). Lippershey claimed his device could magnify an image up to three times. While that is hardly a bold claim from today's vantage point, it was the first important step towards building the many telescopes that now grace the world; after hearing about Lippershey's invention, Galileo designed his own telescope which magnified images up to 20 times, and the field of astronomy was born.

In the 400 years since then, telescopes have become significantly larger. The twin optical and infrared telescopes at the W. M. Keck Observatory in Hawaii, sit near the top of the dormant volcano, Maunakea, at an elevation of 13,600 feet. Both telescopes have a diameter of 10 metres, enabling researchers to observe the universe to a previously unimaginable degree.

However, while there is a general rule that the larger the telescope, the more detail it should be able to provide, turbulence in the Earth's atmosphere blurs astronomical images. Fortunately, scientists have found a way to overcome this issue.

HOW HAVE SCIENTISTS OVERCOME THE BLURRING EFFECT OF TURBULENCE?

Adaptive optics (AO). This is where deformable mirrors correct the distortion caused by atmospheric turbulence so the telescopes can view the skies in much finer detail. Dr Peter Wizinowich, Chief of Technical Development at Keck Observatory, is an engineer who specialises in optical systems in astrophysics. His work focuses on enabling astrophysics through AO, chiefly by adding new capabilities to one of the world's largest telescopes – the 10-metre Keck I and Keck II telescopes.

WHAT HAS ENABLED THE DEVELOPMENT OF ADAPTIVE OPTICS?

The concept of AO was proposed in 1951 by an astronomer named Horace Babcock. However, it is only in the last few decades that technology has developed to an extent where Babcock's proposal could be realised. Initially, the technology was limited to using bright stars that were relatively close to Earth to measure the distortions introduced by the atmosphere, but in more recent times, lasers have enabled astronomers to observe a much larger part of the sky.

"The key adaptive optics technologies include low noise, fast readout detectors to measure the light, fast computers to determine the corrections, and deformable mirrors to make the corrections," explains Peter. "The key laser technology was to develop a sufficiently bright laser, tuned to the wavelength of sodium to excite the sodium atoms in the Earth's mesosphere at an altitude of ~ 90 km to create the artificial star. In addition, instruments have been designed to make use of the AO-corrected light, including the development of large format, infrared detectors."

Keck Observatory became the first in the world to implement both natural guide star (1999) and laser guide star (2004)

Photo Credit: Andrew Richard Hara

DR PETER WIZINOWICH

W. M. Keck Observatory, California Association for Research in Astronomy, Hawaii, USA

FIELD OF RESEARCH

Optical Science in Astrophysics

RESEARCH

Peter's work focuses on using adaptive optics to improve the capabilities of some of the world's largest telescopes.

AO systems on a large telescope. Thus far, these systems have been used to provide data for more than 1,000 refereed science papers. Peter has led the efforts to improve and upgrade the systems over the past two decades.

WHAT RESULTS HAVE BEEN MADE POSSIBLE BY AO?

"A wide range of solar system, galactic, and extra-galactic science has been facilitated by the angular resolution provided by powerful AO systems on a 10-metre telescope," says Peter. "Prior to AO, the angular resolution of ground-based telescopes was 0.5 arcseconds. Keck AO has improved that resolution by a factor of 10 and the sensitivity to a faint star by a factor of 100."

These improvements have led to many notable results, such as determining there is a supermassive black hole at the centre of our galaxy with a mass of 4 million suns! The capabilities of Keck Observatory's telescopes have led to the creation of the University of California, Los Angeles (UCLA) Galactic Center Group. Under the leadership of 2020 Nobel Prize in Physics winner Andrea Ghez, the Group investigates the innermost regions of the Milky Way and the supermassive black hole at its centre, using the highest angular resolution possible.

Interestingly, Keck Observatory's AO observations also helped astronomers realise Pluto is not a planet, but rather, a dwarf planet.

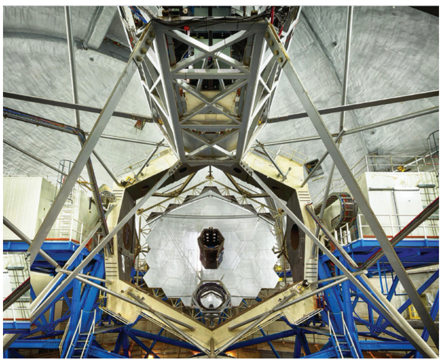
"Pluto is located in the Kuiper Belt. Keck AO measurements revealed the masses of some other Kuiper Belt objects that had moons and were similar in size to Pluto. This led to the discovery of a new class of objects, now called dwarf planets," explains Peter.

WHERE WILL AO AND RELATED RESEARCH LEAD TO IN THE FUTURE?

One of the most important reasons for putting telescopes in space is they are not subject to the atmospheric turbulence that AO seeks to correct. However, telescopes on Earth are far less expensive and easier to maintain – they can be larger, quicker to build, longer lasting, and easier to upgrade.

"Where Keck AO currently works well, at near-infrared wavelengths, it outperforms the much smaller Hubble Space Telescope (10 metres versus 2.4 metres)," says Peter. "However, we can't yet compete with the exquisite image quality of Hubble at visible wavelengths. One of our ultimate goals is to conceptually have the 10-metre Keck telescopes in space (without actually launching them) by having excellent AO-correction at visible wavelengths."

Maunakea hosts some of the most scientifically productive telescopes in the world, making Hawaii an international leader in astronomy. Most of the Maunakea Observatories have optical and infrared telescopes, but there are also submillimetre telescopes and a radio telescope.



The 10-metre diameter Keck Observatory telescope primary mirror consists of 36 hexagonal segments that are actively controlled with nanometer precision to work in concert as a single piece of reflective glass.

The Keck I and Keck II telescopes using their laser guide stars to observe the supermassive black hole at the centre of the Milky Way galaxy. The lasers excite sodium atoms in the Earth's mesosphere to create an artificial star that can be used to measure atmospheric turbulence.

ABOUT OPTICAL SCIENCE AND ASTROPHYSICS

In 1835, the French philosopher Auguste Comte said the chemical composition of stars could be an example of knowledge that might forever be hidden from humankind. However, unbeknownst to him, the development of spectroscopy (the study of the absorption and emission of light and other radiation by matter), was already leading to some exciting discoveries.

In the two centuries since then, we have come an incredibly long way. Humankind has been on the Moon, rovers have landed on Mars, telescopes have been put into space, and observatories around the world are discovering aspects of the universe that would have defied belief even just a few decades ago. Many of these observations have been made possible by the work of scientists like Peter, whose work on adaptive optics has enabled new astrophysics.

WHAT DOES PETER FIND MOST CHALLENGING ABOUT HIS WORK?

Peter has been at Keck Observatory for almost 30 years and in that time has overcome many technical and project management challenges. "One of the biggest challenges for someone like myself who wants to see new science capabilities come to life is finding the funding. So, I spend time working with our science community to identify the future needs and our technical team to figure out how we are going to meet those needs, and then making proposals to both public and private organisations to fund these projects," explains Peter. "We have been quite fortunate to have groups support us like the W. M. Keck Foundation, the Gordon and Betty Moore Foundation, the Heising-Simons Foundation, the National Science Foundation, NASA, and others. Without their support we wouldn't be able to make our dreams come true."

HOW DOES IT FEEL TO HELP CAPTURE IMAGES OF THE UNIVERSE THAT NO ONE ELSE EVER HAS?

Peter says he feels very lucky to be part of the journey of discovery and to help enable those discoveries. Not an astrophysicist himself, it is his engineering expertise that has enabled plenty of talented and creative people to answer many of the big science questions. Without the efforts of people like Peter, it simply would not be possible to observe our universe in the detail that we currently can.

THE KECK ALL-SKY PRECISION ADAPTIVE OPTICS (KAPA) PROJECT AIMS TO INCLUDE MORE WOMEN AND UNDERREPRESENTED MINORITIES IN THIS FIELD. HOW SUCCESSFUL HAS THIS BEEN?

"We are already blessed in the Keck community and the KAPA project leadership to have a lot of female astronomers and students. Our project scientist, two of the four KAPA key science project leads, and our education lead are women. We would like our community and team to include more underrepresented people," says Peter. "More specifically, we would like to attract more women, local Hawaii residents, and minorities into instrumentation and engineering, and retain them in our community."

To achieve this goal, the AstroTech Summer School has been established. Unfortunately, the COVID-19 crisis has led to the cancellation of the first full event planned for 2020, but the team is looking at other ways to bring students together to support their future. The summer school aims to introduce late undergraduate and early graduate students to the process of designing and building a science instrument by providing extensive hands-on experience.

The KAPA project also hosts college students from Hawaii through the Akamai Internship Program.

HOW TO BECOME AN OPTICAL SCIENTIST:

- The Optical Society, of which Peter is a member, provides some useful information about the application of optics, as well as giving some interesting historical facts: **https://www.osa.org/en-us**, **https://www.osa.org/en-us/history**
- Peter is also a member of the engineering-orientated SPIE (The International Society for Optics and Photonics): **https://spie.org/education/education-outreach-resources**
- Study.com provides detailed information about the skills and qualifications required: **https://study.com/articles/optical_engineer_salary_job_description.html**
- Degrees in optical science, optical engineering, optics, or physics will help you in this field. Study.com provides detailed information about different degrees: **https://study.com/articles/Optical_Sciences_Degree_and_Course_Information.html**
- According to Study.com, the median annual salary for an optical engineer is $89,540.

PATHWAY FROM SCHOOL TO OPTICAL SCIENCE

Peter says a good basis in mathematics and physics will serve budding engineers and astrophysicists well, and the opportunity to do research projects and gain confidence and experience is important. "I play an engineering and project leadership role at Keck Observatory. The observatory's technical staff includes electronics, mechanical, optical, and software engineers, technicians, and astronomers," says Peter. "I find it very useful to maintain an overall system perspective, while bringing my own expertise to projects. Having some understanding of each of these disciplines is useful for communication and to know where a problem can be best addressed."

HOW DID DR PETER WIZINOWICH BECOME AN OPTICAL SCIENTIST?

DID YOU ALWAYS WANT TO BE A SCIENTIST?

Astronomy interested me from a young age. I was especially intrigued by how much astronomers could learn just from light. They seemed to be the most clever and inventive detectives to me! Science fiction also played a role in my interests beyond our planet. I studied physics and astronomy in college and eventually found myself more interested in – and my talents more suited to – building the astronomical instruments as opposed to doing the astronomy myself. This led to my pursuit of a PhD in optical sciences after working in astronomical observatories for several years.

WHO OR WHAT HAS INSPIRED YOU IN YOUR CAREER?

The mysteries of the universe are pretty inspiring and being able to play a role in understanding those mysteries is always inspirational – I love being part of an observatory. I have enjoyed working at a research level at universities, but I prefer turning research concepts into working science capabilities. I have managed to work with some very talented people who have challenged me, taught me, and helped me up my game throughout my career.

WHAT ARE SOME OF THE DAY-TO-DAY OBSTACLES YOU FACE IN YOUR WORK AND HOW DO YOU OVERCOME THEM?

What I really enjoy doing is developing an initial concept then taking it through all the steps and challenges to something that is working operationally every night to enable new science. There are day-to-day challenges involving project management, technical issues, and distractions from other aspects of my role. However, knowing these are just part of the process helps overcome the little day-to-day obstacles. There have been many larger challenges over the years, but experience tells me these will be behind us one day and we will find a way to get our work done.

WHAT ARE YOUR PROUDEST CAREER ACHIEVEMENTS?

At Keck Observatory, some of my proudest achievements have included the telescopes, the adaptive optics systems, and the interferometer that combined the light from the twin Keck telescopes. I have had an opportunity to play a leading role in each of these. I'm also pleased to have played a role in the development of engineers and postdocs at Keck Observatory, and to have developed collaborations with AO groups and people around the world. It is a great community to be a part of. I am proud of starting the AO programme at Steward Observatory (prior to my time at Keck Observatory), my PhD research, and early career roles at the Canada-France-Hawaii Telescope and the University of Toronto telescope in Chile.

HOW DO YOU 'SWITCH OFF' FROM THE COMPLEXITIES OF YOUR WORK?

I'm not sure I switch off enough! However, I do enjoy swimming, hiking, biking, reading, travelling, and spending time with my family.

Photo Credit: Andrew Richard Hara

HOW TO BECOME AN ASTROPHYSICIST:

- The American Astronomical Society is a robust resource for those interested in understanding the universe. There is a section dedicated to career information and advice, including internships and summer jobs: **https://aas.org**
- The National Space Society is another brilliant resource. There are even contests and competitions you can participate in: **https://space.nss.org**
- You'll usually need a degree and postdoctoral experience to work as an astronomer. Relevant subjects include math, physics, astrophysics, geophysics, astronomy, and space science: **https://nationalcareers.service.gov.uk/job-profiles/astronomer**
- Study.com also has useful guidance on astronomy and has the median annual salary at $105,680: **https://study.com/articles/Astronomer_Job_Information_and_Requirements_for_Students_Considering_a_Career_in_Astronomy.html**

PETER'S TOP TIPS FOR STUDENTS

1 Find an area of scientific interest that you enjoy and where you want to make a contribution. Knowing that you're doing something worthwhile will help you get through challenging times.

2 Never be afraid to explore ideas and take opportunities to challenge yourself. When you find you are up to the challenge, this will increase your confidence and allow you to move on to bigger challenges.

3 Keep in mind you will struggle at times and make mistakes – these are opportunities to learn and grow. It helps to have your eye on longer-term goals as you address the obstacles that will lie along the path toward those goals.