Michael Bolte

Professor of Astronomy and Astrophysics, University of California, Santa Cruz
Director Emeritus, University of California Observatories

I am a faculty member in the Department of Astronomy and Astrophysics at the University of California, Santa Cruz (UCSC). I am also the former Director of the University of California Observatories. This is a University of California multi-campus research unit that manages the UC optical/infrared facilities: Lick Observatory, the W.M. Keck Observatory (jointly managed with Caltech) and extensive laboratory facilities. I am a member of the Board of Governors of TIO.

Astronomy

Astronomy is one of the oldest of the sciences. It is the study of the contents, origin, evolution and fate of the Universe. Astronomy research has played a large role in defining humankind's place in the Universe. With the unaided eye, it is possible to see a few thousand stars from any one dark location on Earth. Studies of the heavens in this way were the basis of timekeeping and navigation going back at least 5000 years. However, the invention of the first small telescope and its use by Galileo to explore the heavens in much greater detail fundamentally changed our understanding of the Universe and the context of the Earth in that Universe. As telescopes became larger and instruments more sensitive, we have come to the realization that the Earth is one of billions of planets in a galaxy of approximate 300 billion stars and that galaxy is one of approximately 100 billion galaxies in the observable Universe. Astronomy and astrophysics research have led to the elucidation of the fundamental laws of physics. Tools developed for astronomical research have also been the basis of many "spinoff" technologies. Recent examples are the use of adaptive optics, originally developed to remove the blurring of the atmosphere for astronomical observations, to greatly aid many areas of vision science and eye disease research and the use of computer algorithms designed to

discover large scale structure in the Universe to make very early detection of breast cancer tumors in mammogram images.

Astronomy is also the science that has most captured the public's interest and imagination. Newspaper and web-based news articles about astronomy discoveries outnumber those for all other sciences. More university students in the US take introductory astronomy classes (estimated at 200,000 students per year) than any of the other sciences and astronomy is considered an important "gateway" science for interesting students in science and technology fields. This has been identified as a key national need. At my university we sponsor a series of public lectures on recent astronomy discoveries that are wildly successful and even using the largest venues available, we routinely turn people away. Astronomy research is an extension of centuries of humankind's exploration of the environment in which we live.

In the US, there are approximately 6000 professional astronomers. It is estimated that between 300,000 and 500,000 people in the US are members of amateur astronomy clubs or groups or regularly use their own telescopes. The number estimated to attend planetarium shows is substantial, in the tens of millions worldwide.

Astronomy From Maunakea

The observatories on Maunakea are among the best in the world - located at one of the best locations in the world for astronomy. They have contributed to some of the very most important scientific findings of our time. These have advanced our understanding of the nature of the Universe, and our place therein. They have helped us find some of the earliest objects that formed in the Universe, over 13 billion years ago, and also helped us explore planets orbiting stars in our own Milky Way galaxy.

These discoveries have not only excited astronomers, but have enamored the world as a whole. Recently in an article in the New York Times - http://www.nytimes.com/interactive/2016/10/03/science/hawaii-mauna-kea-telescope-discoveries.html?_r=0 - a Maunakea "top five" was presented, each of

which were enabled by the outstanding and unique capabilities of the observatories in Hawaii:

- Dark Energy and the Accelerating Universe

Two teams of astronomers used the telescopes in Hawaii to study objects known as type IA supernovae, which result from the collapse of white dwarf stars. They demonstrated that as the universe expands, its rate of expansion is increasing. For this work the leaders of both teams were awarded the Nobel Prize in physics in 2011.

- Looking Back Towards the Beginning of Time

The telescopes on Maunakea offer an opportunity to look back in time and study some of the very first objects to form in the Universe. Using the Keck telescope, astronomers determined the distance to a galaxy that came into existence only six hundred seventy million years after the Big Bang. It is one of the earliest galaxies for which a reliable distance has been measured.

- The Black Hole at the Center of the Milky Way

At the center of our galaxy lies a massive black hole, with a mass of as much as four million times the mass of our own Sun. Using adaptive optics at the Keck observatory on Maunakea, Andrea Ghez (UCLA) and other astronomers were able to demonstrate the existence of and calculate the mass of this black hole.

- Seeing Planets Around Other Stars

Using the adaptive optics at the Gemini North and Keck telescopes on Maunakea, astronomers provided one of our first-ever direct images of planets around another star. There are as many as five planets that orbit the star known as HR 8799, approximately 130 light-years from Earth.

- Life Everywhere?

Thousands of planets and planet candidates have been revealed by NASA's Kepler observatory. The planet Proxima b, which orbits our nearest neighboring star, could even be Earth-like and habitable. The Keck telescopes have been the premiere observatories for confirming candidate planets and enabling studies of their properties.

The Role of the TMT

Because the vast majority of our knowledge of the Universe has been inferred from very faint light sources often at enormous distances, progress in our understanding of the Universe has depended on advancements in astronomy facilities starting with Galileo's first use of a telescope to establish the sun centered model for the solar system. The TMT is the next step on a path that began with Galileo. TMT will allow astronomers to explore virtually every field of astrophysics, from the creation of the universe to exoplanets (planets around stars other than our sun). The resolution and sensitivity provided by TMT's large aperture and adaptive optics systems, combined with a flexible and powerful suite of instruments, will enable us to address the most fundamental questions of the coming decades. These include:

- What is the nature and composition of the Universe?
- When did the first galaxies form and how did they evolve?
- How do stars and planets form?
- What is the nature of planets around other stars?
- Is there life elsewhere in the Universe?

Studies of TMT capabilities have shown that it should be possible to detect so-called "bio-markers" in some extra-solar planets. These are the chemical signatures of life in the atmospheres of the exoplanets. Now I will admit that we don't know for certain TMT will be the telescope that first finds bio-markers outside our solar system. The thing that excites me, however, is that it's possible. And this is only one example of the cutting-edge, frontier science that TMT will enable. I do not think it's an exaggeration to say that finding evidence of life outside our solar system will be a transformative moment in human history. As our view changed with Copernicus – moving the Earth from the center of the universe – so may it change as we find evidence for life outside of our own planet.

TMT - An International, Pan-Pacific Observatory

The TMT at Maunakea would create an astronomical ecosystem with enormous capability. The TMT partners have other telescopes that would continue to be powerful in their own right and work together with the TMT. The most interesting systems would be identified by the existing telescopes for follow-up at the highest spatial resolution and sensitivities with the TMT.

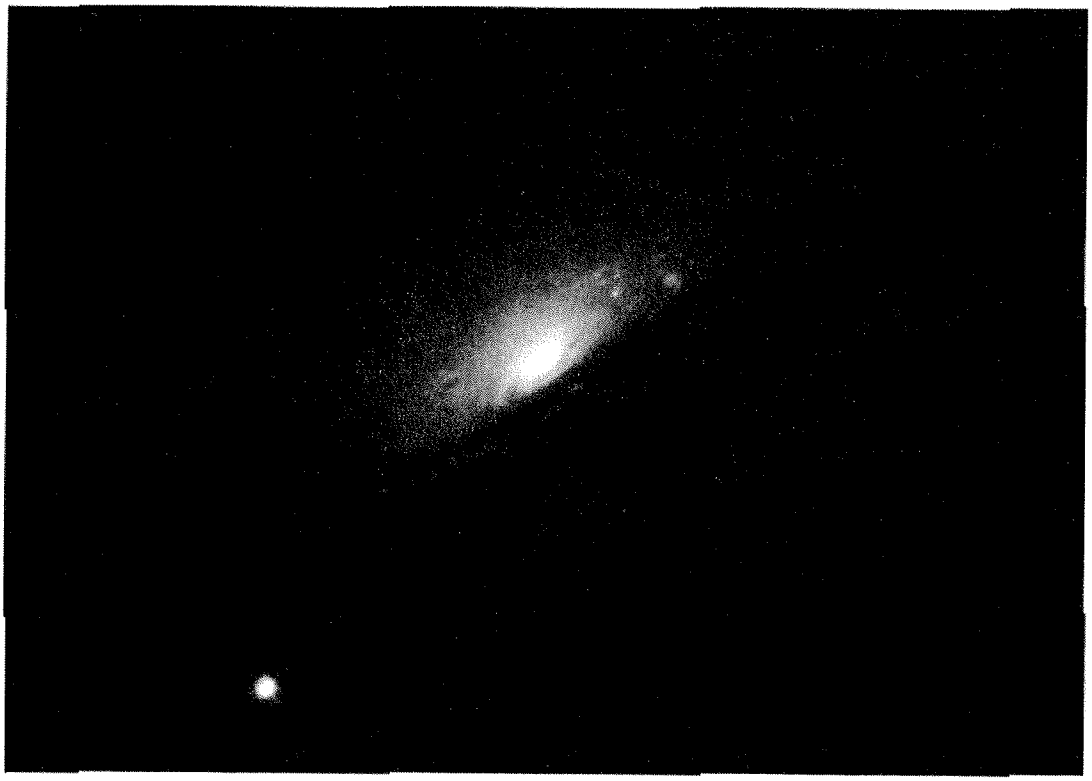
I've dedicated a significant fraction of my career working on the TMT concept. In recent years, my commitment to TMT has been reaffirmed by my colleagues throughout astronomy. Not only has the U.S. astronomical community affirmed a thirty-meter class telescope as a top priority for this decade, but we have been joined by colleagues around the world, including Canada, Japan, China and India. It is personally gratifying to see that this project is embraced around the world, and leading technology nations are partners in the project. If built, it will be one of the great science facilities of this century.

The New York Times, Oct. 3, 2016
From Hawaii's Mauna Kea, A Universe of Discoveries

http://www.nytimes.com/interactive/2016/10/03/science/hawaii-mauna-kea-telescope-discoveries.html

By DENNIS OVERBYE and MICHAEL ROSTON

Mauna Kea is a sacred place for native Hawaiians. For astronomers, it is also a vital location. From the top of this dormant volcano, telescopes have helped advance important discoveries in humanity's study of the universe. The observatories on Hawaii have contributed to several recent important scientific findings.



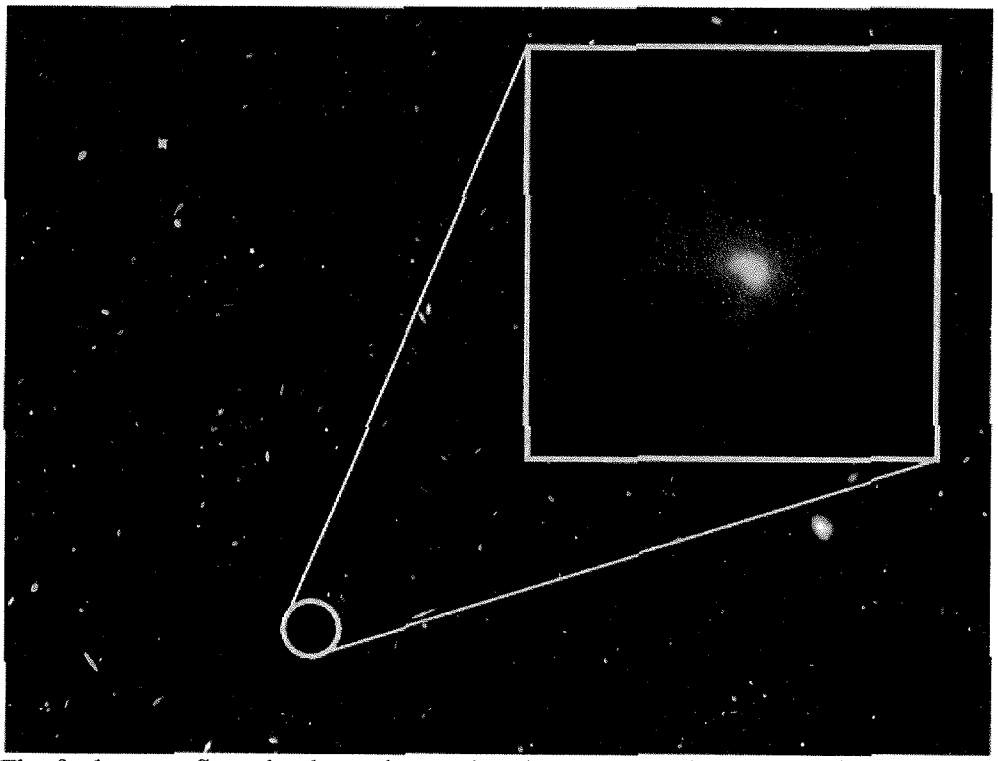
In the outskirts of disk galaxy NGC 4526 is supernova 1994d in the bottom left corner. It is a type IA exploding star, which astronomers use to estimate the speed of the expansion of the universe.
Credit: High-Z Supernova Search Team/HST/NASA

Dark Energy and the Accelerating Universe

All of the galaxies in the universe are going places, and they're in a hurry to get there. Seemingly driven by mysterious dark energy or vacuum energy, astronomers observed that as the universe expanded, it was speeding up. And the Keck observatory at Mauna Kea played a crucial role in making this discovery.

Two rival teams of astronomers used the telescopes in Hawaii to examine a large inventory of distant type IA supernovae, which result from the collapse of white dwarf stars. The uniform brightness of these supernovae make them ideal beacons for measuring cosmic distances, which allows scientists to accurately estimate the speed of cosmic expansion.

While the competition between the two groups of researchers was fierce, leaders of both teams were awarded with the Nobel Prize in physics in 2011.

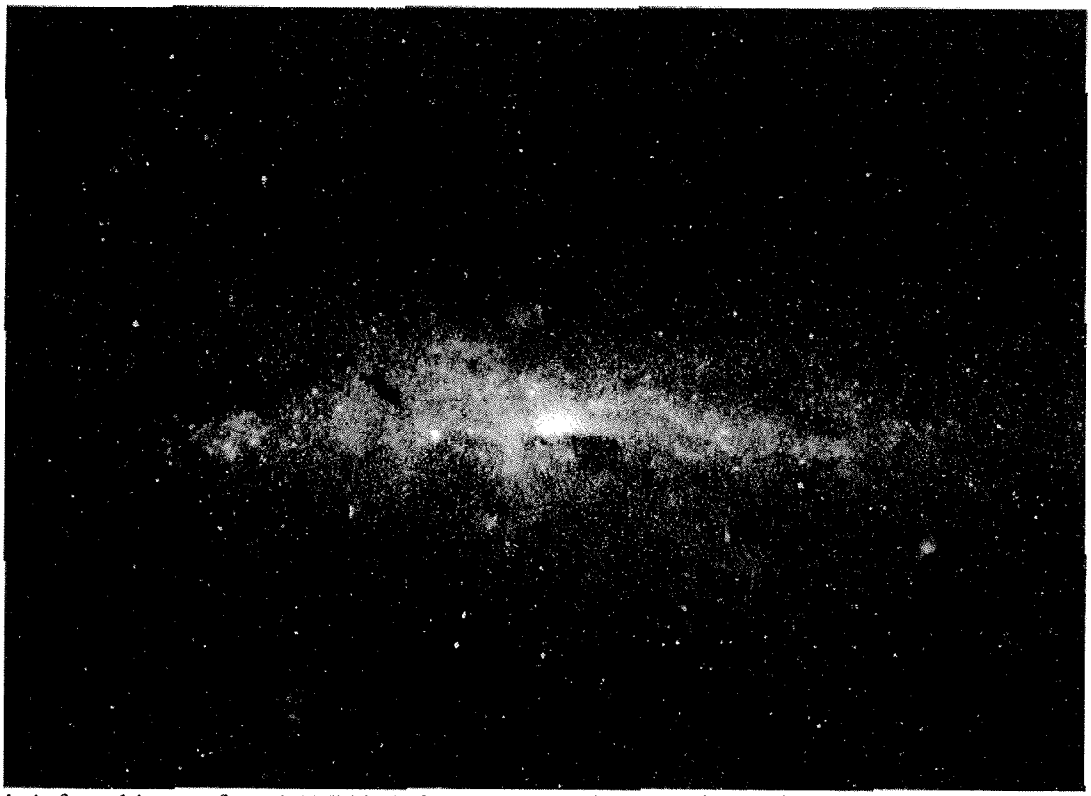


The farthest confirmed galaxy observed to date was identified in this field of galaxies recorded by the Hubble telescope.
Credit NASA/European Space Agency/Yale/University of California, Santa Cruz

□The Universe in Its Infancy

Six hundred seventy million years may seem like a long time, but that many years after the Big Bang, the universe was a mere infant. Somehow a galaxy called EGS-zs8-1 bloomed into existence at that point. It is one of the earliest galaxies for which a reliable distance was measured.

This former galactic youngster, now billions of years old, was first observed by other telescopes. To confirm its age, astronomers used a powerful spectrograph at Mauna Kea called Mosfire. This device measured the redshift, or its light broadening to longer wavelengths, of EGS-zs8-1. Studying early galaxy formation is one objective of the stalled Thirty Meter Telescope project.



This infrared image from NASA's Spitzer Space Telescope shows the center of the Milky Way galaxy, where a black hole may lurk.

Credit

NASA/JPL-Caltech

Measuring the Milky Way's Central Behemoth

At the center of our galaxy probably lies a monstrous black hole. This supermassive trapdoor has a steady diet of matter, and it has a mass of as much as four million suns.

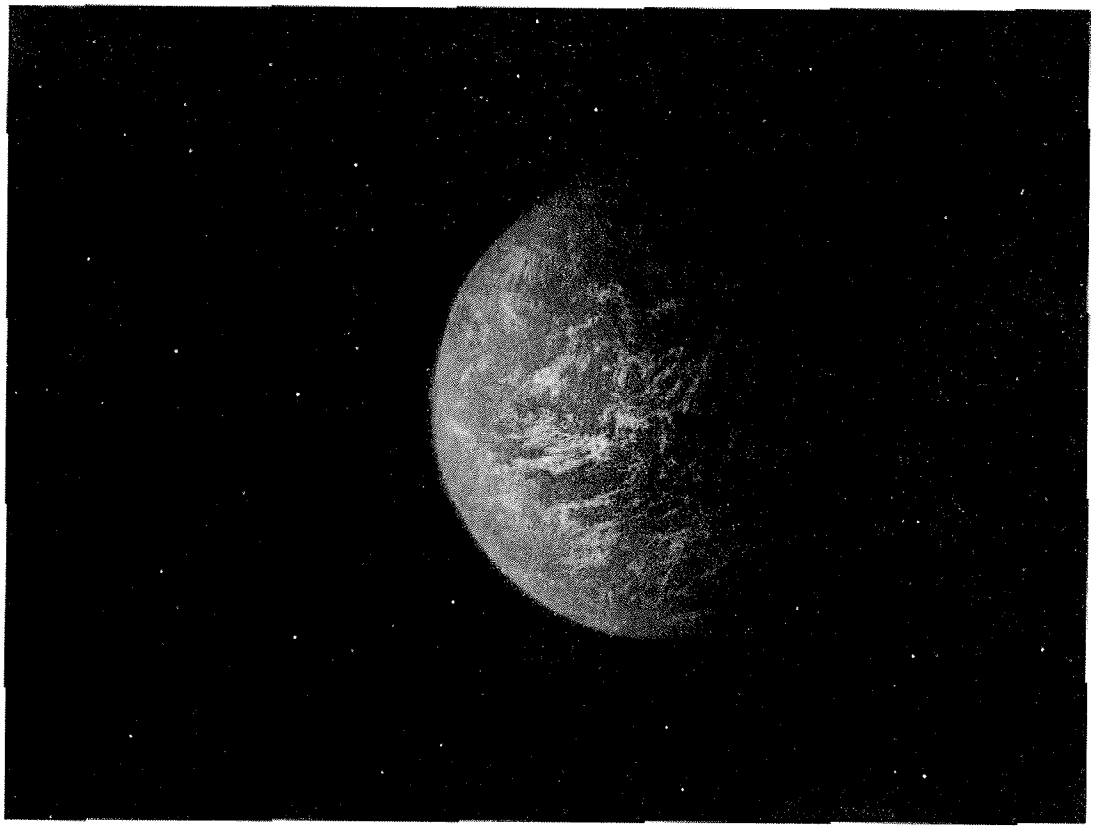
To determine the size of this object at the center of the Milky Way, Andrea Ghez of U.C.L.A. has studied the motions of stars as they orbit this object. Using adaptive optics on the tennis-court-size telescopes at the Keck observatory on Mauna Kea, Dr. Ghez and other astronomers were able to scrutinize stars that were much closer to the galactic center than previously observed and calculate the mass hiding in its black hole.

There may be as many as five planets orbiting around the star HR 8799, which is 130 light-years from our solar system.
Credit National Research Council of Canada, Christian Marois & Keck observatory

'First Glimpse of Planets Around Another Star

There are planets around our sun. One can assume there are many more planets around many other stars. Science does not assume.
Astronomers had detected the existence of planetary bodies well beyond our solar system. But seeing is believing, and studies of HR 8799, a star 130 light-years from our world, gave us one of our first glimpses of extrasolar planets.

These giants - the smallest of the three is six times the size of Jupiter - were captured using the adaptive optics of the Gemini North and Keck telescopes on Mauna Kea. There may be as many as five planets orbiting the star.



An artist's rendering of Kepler-22b. Astronomers believe the planet lies in the habitable zone of a sunlike star, and used the Keck observatories to help confirm its radius.

Potential Habitats in the Billions

In the last two decades, planets outside the solar system have been detected by the bushel. Proxima b, which orbits our nearest neighboring star, could even be Earth-like.

Proxima b is probably far from alone among potentially habitable worlds in the universe. With NASA's Kepler spacecraft, thousands of additional Sun-like stars have been surveyed, and one team of researchers found that as many as 22 percent of them could have Earth-size planets in their goldilocks zones, meaning not too hot and not too cold. That could mean as many as 40 billion habitable worlds in our galaxy alone.

The Keck telescopes in Hawaii have served as the main tools for examining and confirming exoplanet candidates detected by Kepler. These eyes on the ground back up what scientists first think they see from the telescopes in space.