

AUTUMN
2010

The free international astronomy webzine

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**The biggest
telescopes
on Earth**



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Publisher, editorial office,
circulation, advertising
Astro Publishing di Pirlo L.
Via Bonomelli, 106
25049 Iseo - Bs - Italy
www.astropublishing.com
info@astropublishing.com

Internet Service Provider
Aruba S.p.A.
P.zza Garibaldi, 8
52010 Soci - Ar - Italy

Legal registration
Tribunal of Brescia - Italy
reference number 51
of the 19/11/2008

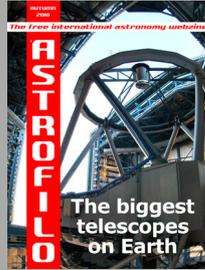
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ON THE COVER

Dramatic image of one of the four 8.2 metre telescopes that make up the Very Large Telescope, situated on the summit of Cerro Paranal in Chile. Photo by Emilio Sassone Corsi, author of the book "Occhi al cielo".

SPECIAL ISSUE

The biggest telescopes on Earth

Foreword

Two important factors in the development of astrophysics during the last twenty years have been the Hubble Space Telescope and the appearance of the so-called 8-metre class telescopes, that actually include many telescopes of over 10 metres, and multiple telescopes with even greater light-gathering power.

This year Hubble has already been celebrated for the twentieth anniversary of its launch, and so we decided to dedicate a special issue to its "bigger brothers", that thanks both to sophisticated technological solutions and their much greater diameters, manage to obtain incredible results despite the hindrance of the terrestrial atmosphere.

Active and adaptive optics now allow ground based telescopes to surpass the performance of those in orbit, at least in some fields of research, while retaining the huge advantage of being easy to maintain and operate. They also do not have a limited lifetime, in contrast to space based observatories, which, sooner or later, are either destined to burn up in the Earth's atmosphere or die quietly in a remote orbit.

Just leafing through this special issue, thanks to the detailed images we've used, you get an idea of the complexity of the great telescopes of our time, and how their structure is so distant from the old telescopes we're used to seeing in the classical observatories. Some of the largest telescopes in the world are actually relatively unknown by the general public, so this could be a good opportunity to learn about them.

Michele Ferrara

The biggest telescope on Earth

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In the last two decades astrophysical research has made giant steps thanks partly to a new generation of large telescopes, located under the clearest skies on Earth. In the pages that follow, we illustrate all those with diameters greater than 8 metres, starting with the recent Gran Telescopio Canarias, the dome of which we see below, against a marvelously clear sky.



Gran Telescopio
Canarias
10,4 metres

Gran Telescopio Canarias

The Gran Telescopio Canarias (GTC), also called GranTeCan, is a reflecting telescope with a primary mirror 10.4 metres in diame-





ter. It's located on the peak of a volcano at an altitude of 2267 metres in one of the best astronomical sites in the northern hemisphere, the "Observatorio del Roque de Los Muchachos" (ORM), on La Palma in the Canaries. The GTC

is a Spanish project overseen by the Instituto de Astrofísica de Canarias (IAC). The telescope is supported by both the Spanish and local government through European Regional Development Funds (FEDER) from the

European Union. The other institutions collaborating in the project are the Instituto de Astronomía del Universidad Nacional Autónoma de México (IAU-NAM), the Instituto Nacional de Astrofísica, Óptica y Electrónica



(INAOE) and the University of Florida (UFL). At the moment it's the largest single aperture telescope in the world. The primary mirror is made up of 36 hexagonal segments all controlled by an active optics system. It



took seven years to build between 2002 and 2008. First light was on 13th July 2007, but scientific observations didn't start until May 2009. The main instruments are CanariCam (Florida University), a mid-infra-



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red camera with spectrograph, coronagraph and polarimeter mounted at the Nasmyth focus, and Osiris (Optical System for Imaging and Low Resolution Integrated Spectroscopy) a low/medium resolution spectro-

graph for visible wavelengths.

Telescope web site:

www.gtc.iac.es/en

Sito web IAC:

www.iac.es/index.php?lang=en

Credits: GTC Project Team, Pablo Bonet, M. Paiva Duarte.



Keck I and II
telescopes
10,0 metres

The Keck I and II telescopes

Situated at an altitude of 4145 m on the summit of Mauna Kea, Hawaii, the American twin Ritchey-Chrétien telescopes Keck I and Keck II began operations in

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1993 and 1996 respectively. The Keck Observatory is operated by the California Association for Research in Astronomy, a non-profit organisation whose members include representatives from Caltech and the University of California. The con-

struction of the two telescopes was made possible by private funding of over 140 million dollars from the W. M. Keck Foundation. NASA began collaborating with the project in 1996. The primary mirror of each telescope is 10 m in diameter,



making them the world's largest telescopes after the Gran Telescopio Canarias. The mirrors are not monolithic but composed of 36 hexagonal segments, each one maintained in the correct position within the extremely rigid frame by the

16

actuators of an active optics system. They can operate either singularly, or together, as an interferometer with a baseline of 85 m (the distance between them). Both telescopes are equipped for visible and infrared observations. The telescopes

have an adaptive optics system that compensates for the distortion caused by atmospheric turbulence, the first system of its kind to be installed on a large telescope. The project is part of NASA's "Origins" program (<http://planetquest.jpl.nasa.gov>);

a program to observe the formation of the first stars and galaxies, to search for planets around other stars, search for life forms in the Universe and investigate the beginnings of life on Earth.

Web site of Manua Kea Observatory,

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University of Hawaii: www.ifa.hawaii.edu/mko
Web site of the W. M. Keck Observatory: www.keckobservatory.org.

Credits: W.M. Keck Observatory, NASA/JPL, Sarah Anderson, Andrew Cooper (WMKO), E. Sassone Corsi.

Southern African
Large Telescope
9,2 metres

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Southern African Large Telescope

The South African Astronomical Observatory (SAAO) is the national centre for optical and infrared astronomy based in Cape Town (South Africa), established in 1972 and operated by



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the National Research Foundation of South Africa. The SAAO hosts the Southern African Large Telescope (SALT), a 9.2 m reflector made up of 91 hexagonal segments. It's located at 1783 m above sea level, at Sutherland, about 370 kilometres from the Observatories headquarters. Inaugurated in November



2005, the SALT is the largest single optical telescope in the southern hemisphere, and can collect at least 25 times as much light as any other African telescope, allowing it to observe very distant stars, galaxies and quasars. The construction of SALT was made possible thanks to an international consortium

of partners from South Africa, the U.S., Germany, Poland, India, the U.K., and New Zealand.

Web site web:
www.sao.ac.za

Credits: SALT Consortium/Project Team/Foundation, Matthew Bershad, Jian Swiegers, Dave Buckley.

Hobby-Eberly Telescope 9,2 metres

Hobby- Eberly Telescope

The Hobby-Eberly Telescope is the fourth largest optical telescope in the world. Situated on the summit of Mount Fowlkes, at an altitude of 2030 m, in Texas, it is part of the

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McDonald Observatory. It has an effective aperture of 9.2 m with the primary mirror composed of 91 hexagonal segments, much like the SALT. The telescope is named after the first governor of Texas, Bill Hobby, and a benefactor from Pennsylvania



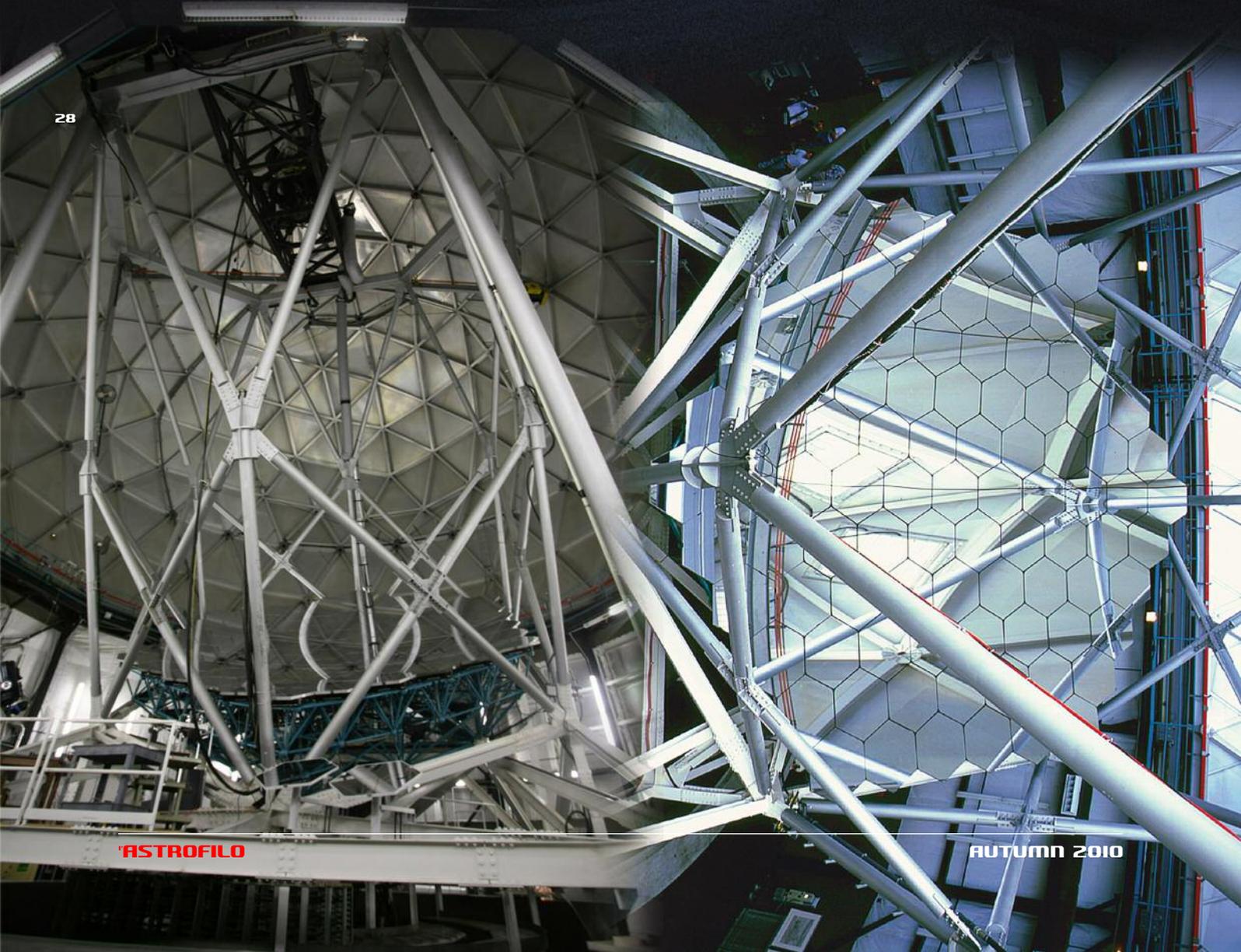


State University, Robert E. Eberly. The telescope is operated by a consortium of institutes including the University of Texas at Austin, Pennsylvania State University, Stanford University, Ludwig Maximilian University in Munich (Germany) and the

Georg August University of Göttingen (Sweden). The HET was designed with spectroscopy in mind: there are three spectrographs with high, medium and low resolution. The low resolution instrument is located directly at the prime focus, while the



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other two are in the base of the telescope.

Hobby-Eberly Telescope web site: www.as.utexas.edu/mcdonald/het/het.html.

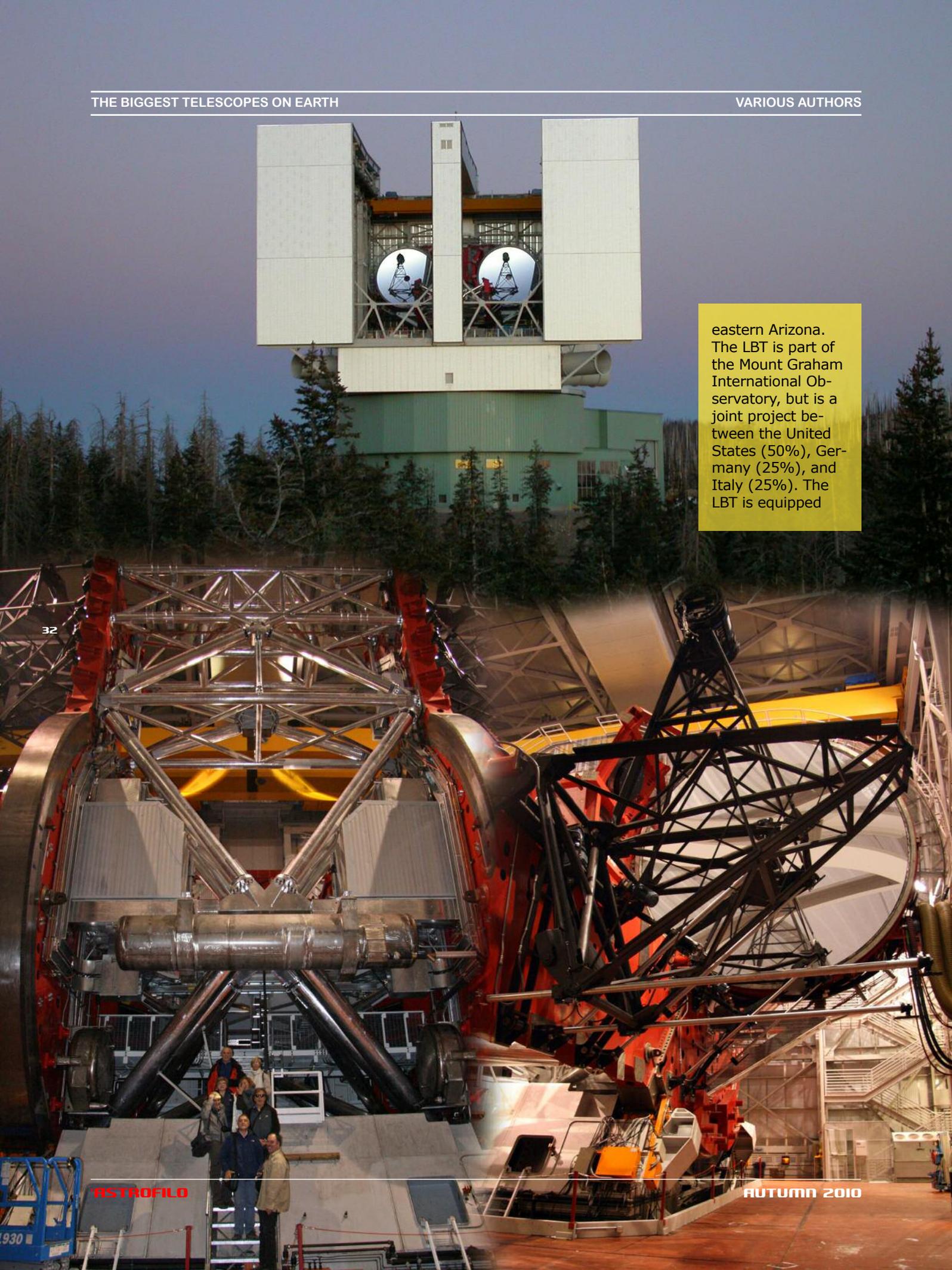
Credits: Lawrence W. Ramsey, Scott Kardel, Marty Harris, Thomas A. Sebring.

Large Binocular
Telescope x 2
8,4 metres

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Large Binocular Telescope

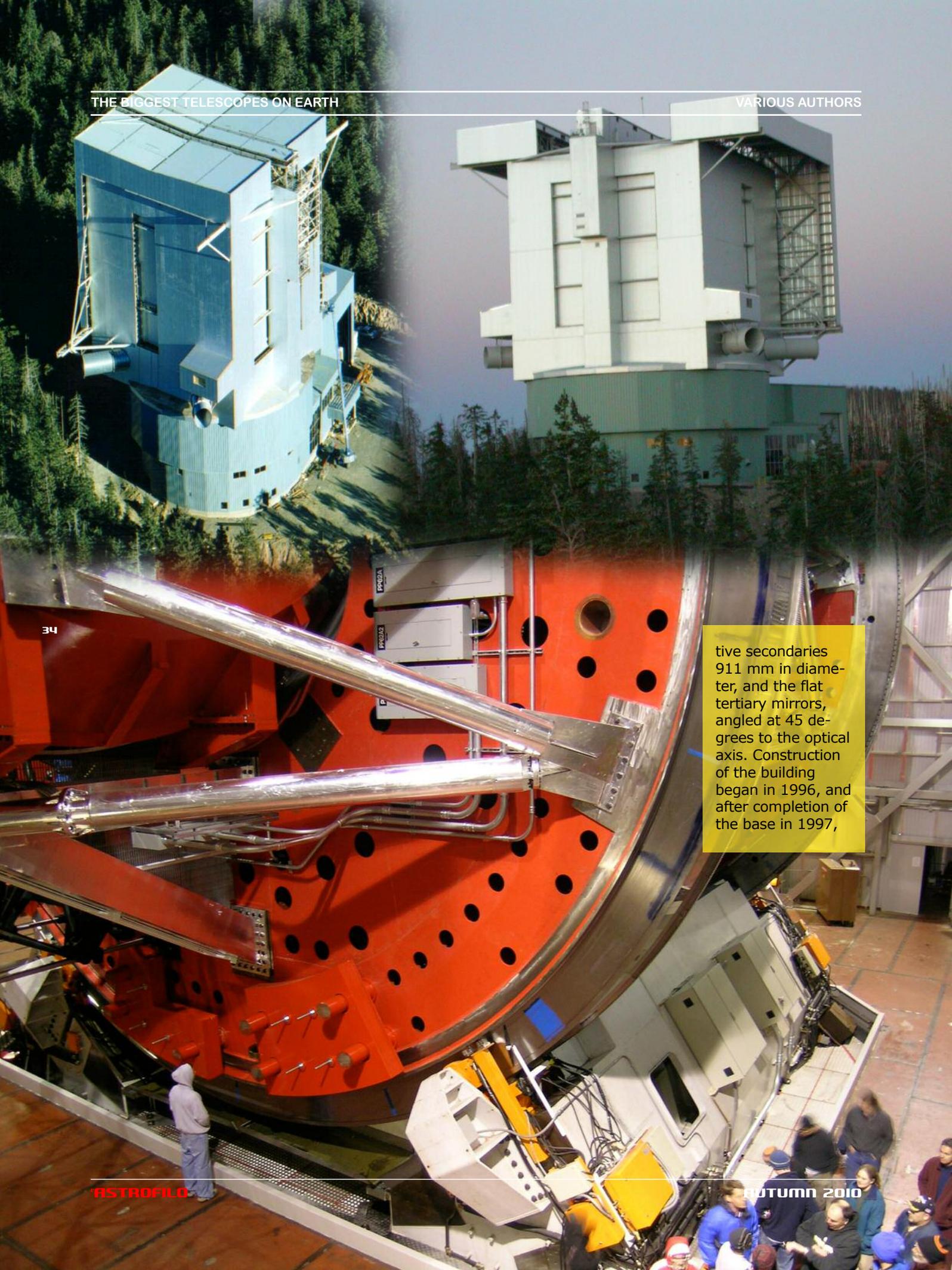
The Large Binocular Telescope (LBT) is situated on Mount Graham at 3300 metres above sea level, in the Pinaleno mountain range, in south-



eastern Arizona. The LBT is part of the Mount Graham International Observatory, but is a joint project between the United States (50%), Germany (25%), and Italy (25%). The LBT is equipped

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with three pairs of mirrors: the two primary parabolic mirrors 8.4 metres in diameter (complete with active optics system to correct for deformation caused by their own weight), the concave adap-

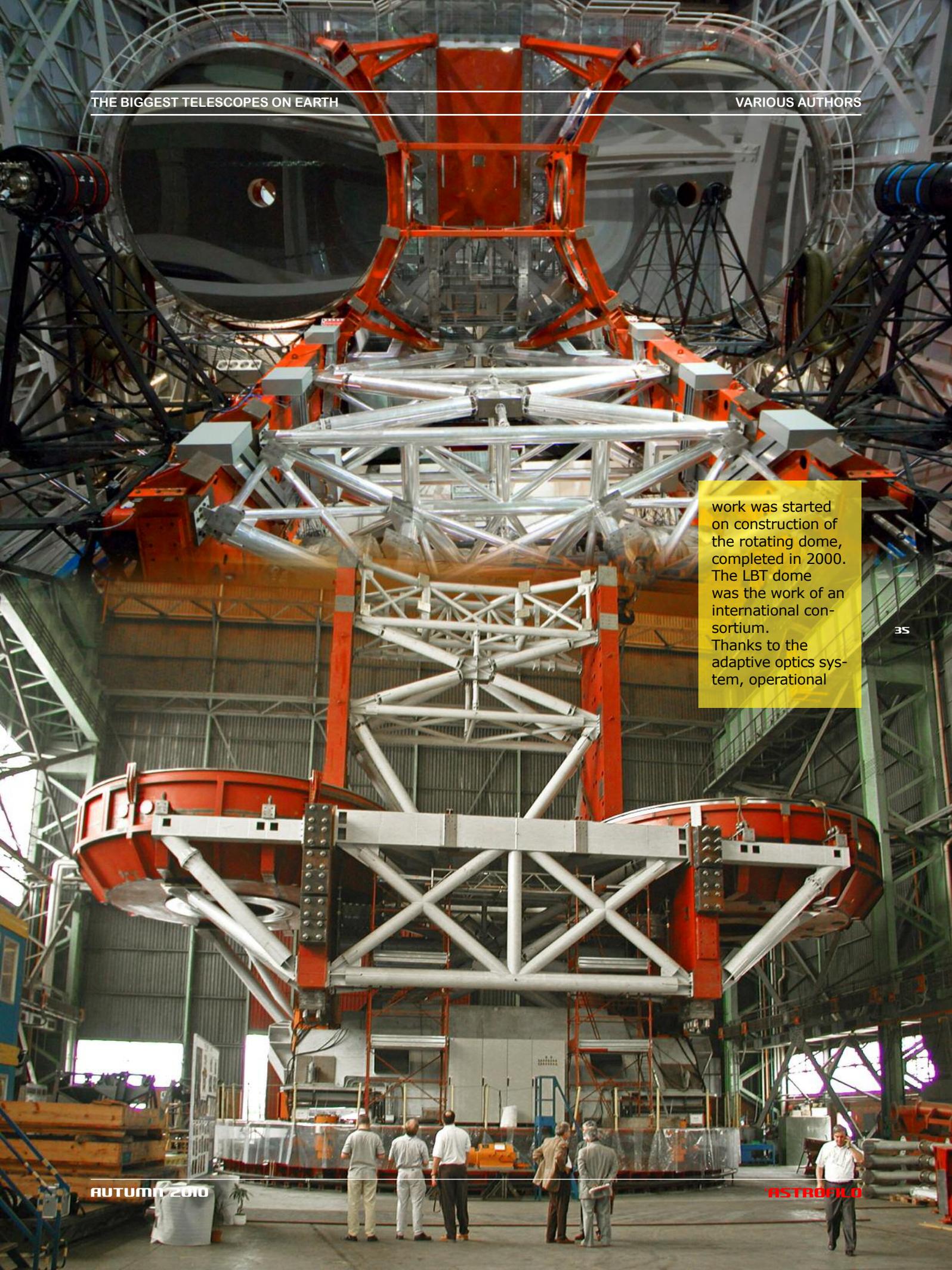


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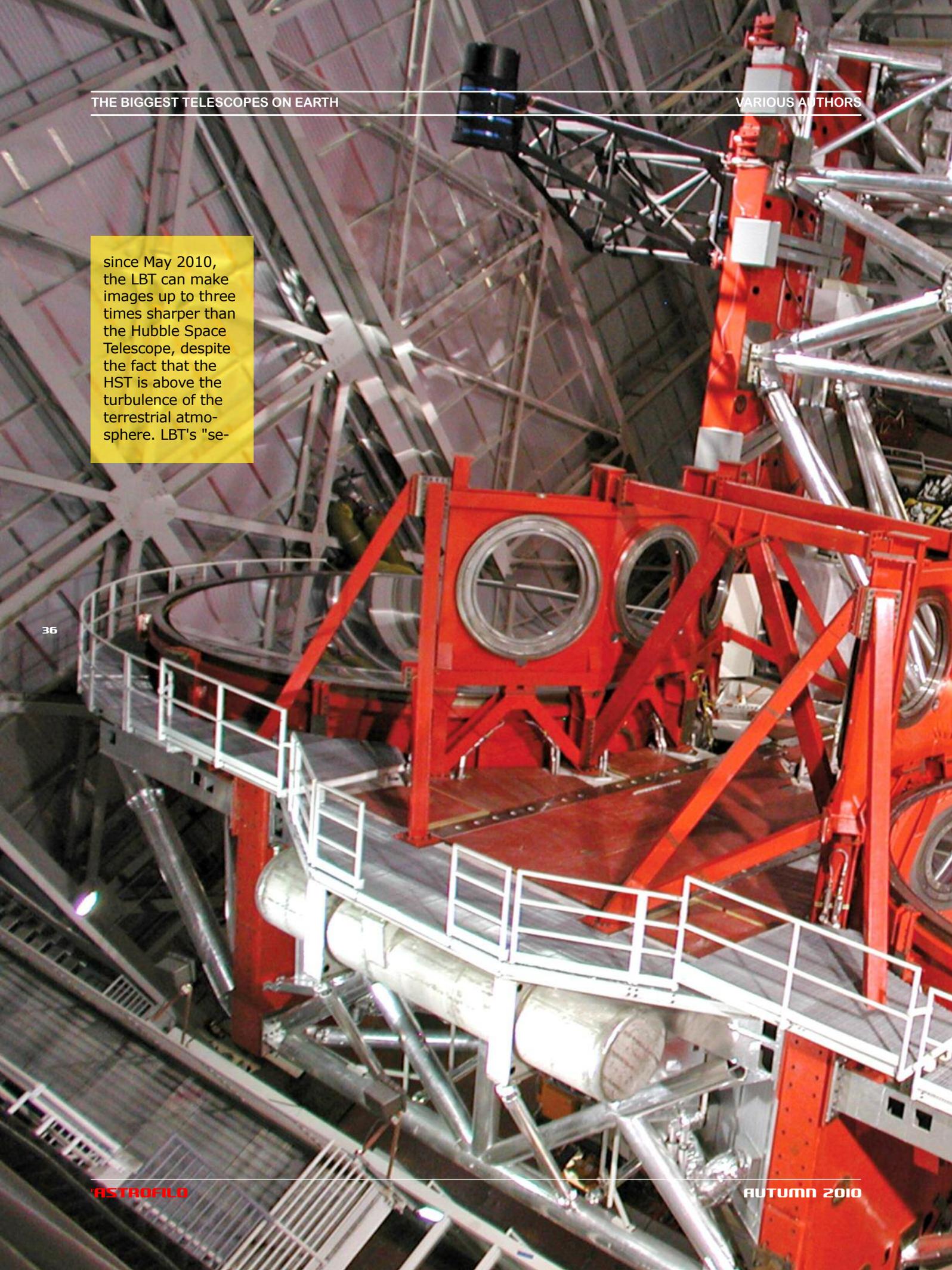
tive secondaries 911 mm in diameter, and the flat tertiary mirrors, angled at 45 degrees to the optical axis. Construction of the building began in 1996, and after completion of the base in 1997,

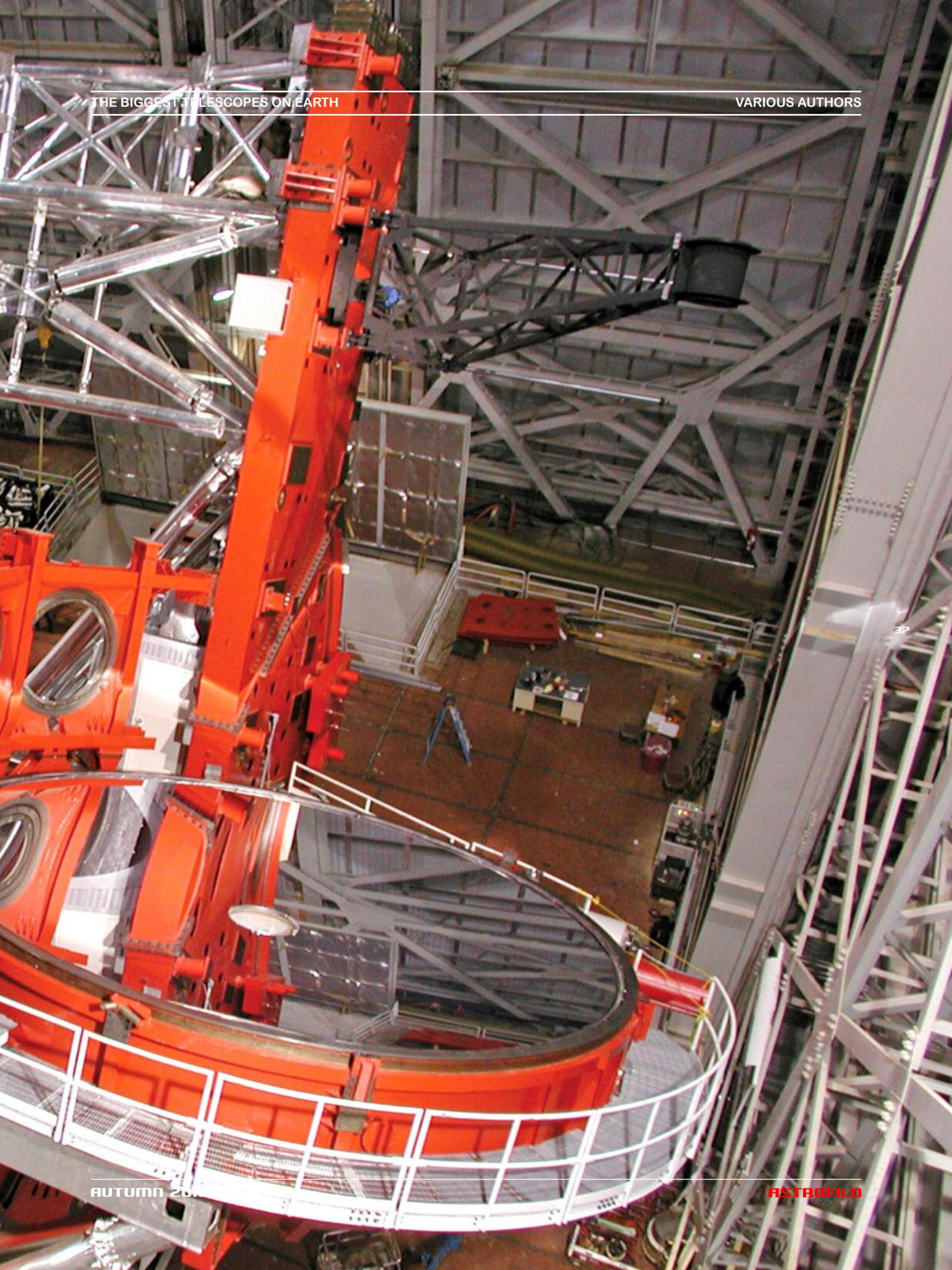
work was started on construction of the rotating dome, completed in 2000. The LBT dome was the work of an international consortium. Thanks to the adaptive optics system, operational

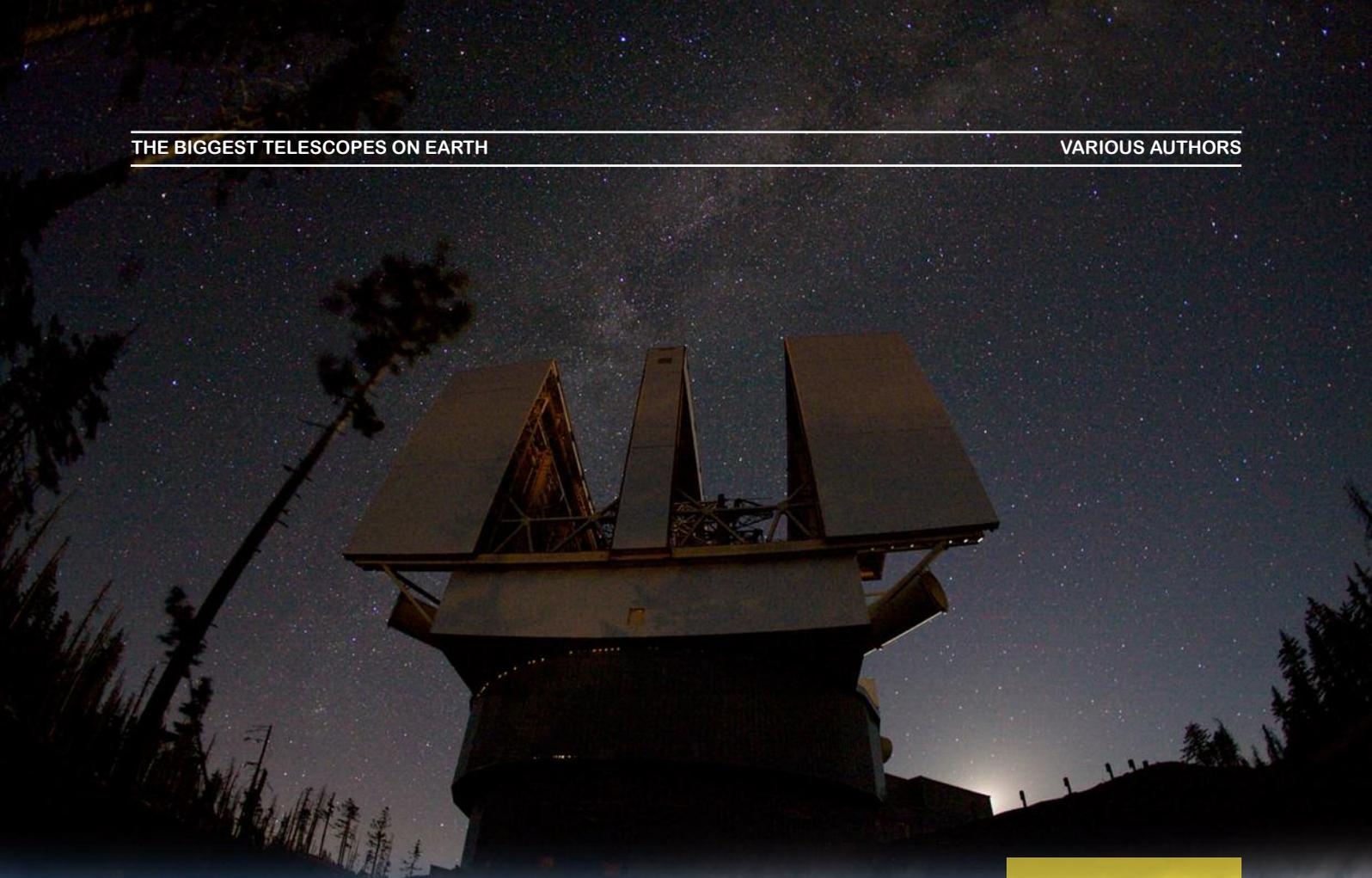
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since May 2010, the LBT can make images up to three times sharper than the Hubble Space Telescope, despite the fact that the HST is above the turbulence of the terrestrial atmosphere. LBT's "se-







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cret" is the First Light Adaptive Optics (FLAO), an innovative system directly connected to the 91 cm secondary mirror, so that it's an integral part of the telescope, rather than an add-on compo-



nent as in other telescopes. Amongst the instrument lineup at the LBT is LUCIFER and the two Large Binocular Cameras.

Large Binocular Telescope Observatory web site:

<http://medusa.as.arizona.edu/lbto>.

Credits: David Steele, E. Sassone Corsi, Patrick Osmer, MPIA, Stefan Seip, LBT Team, Marc-Andre Besel, Ray Bertram, Aaron Ceranski.



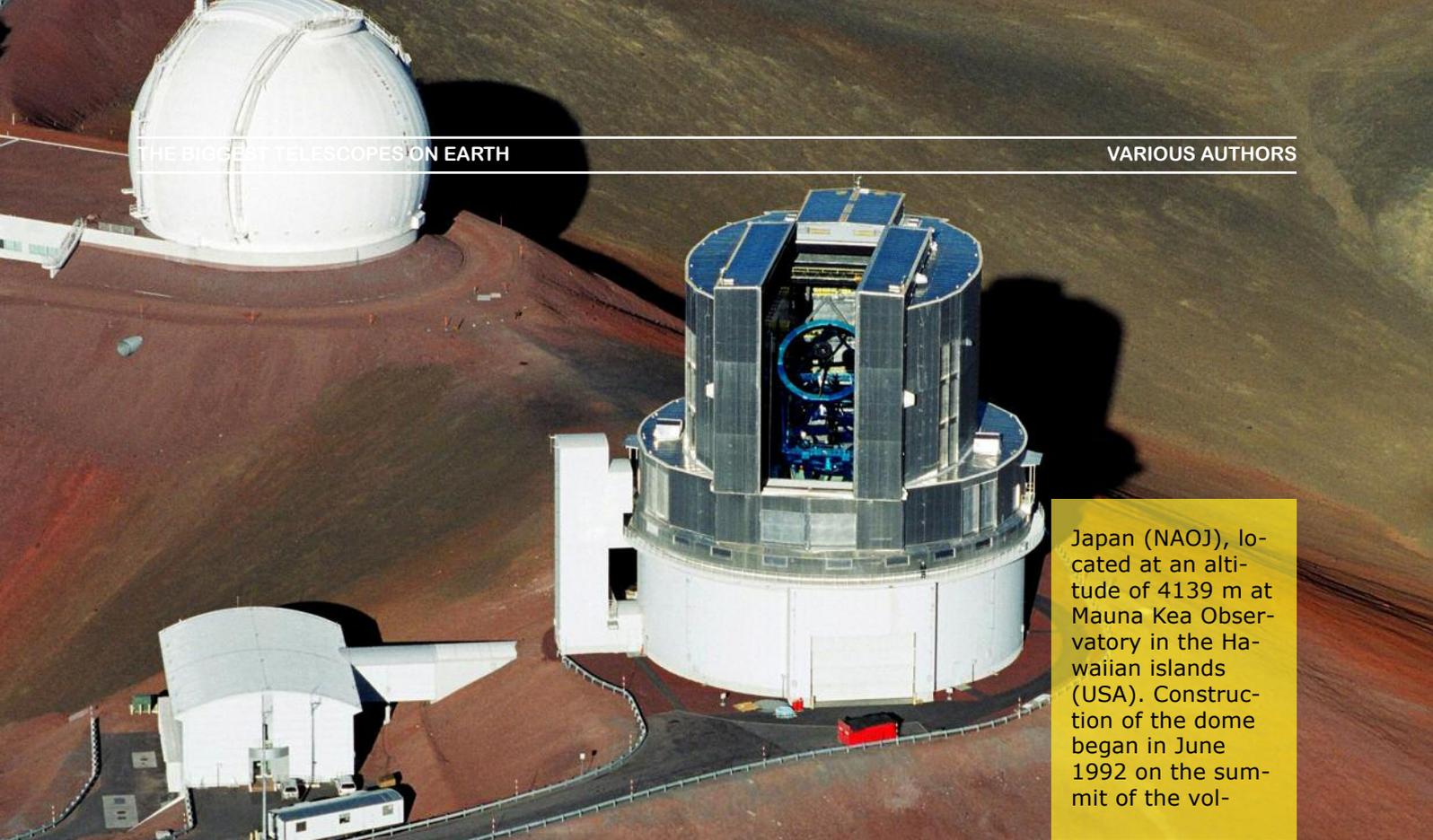


Subaru
Telescope
8.2 metres

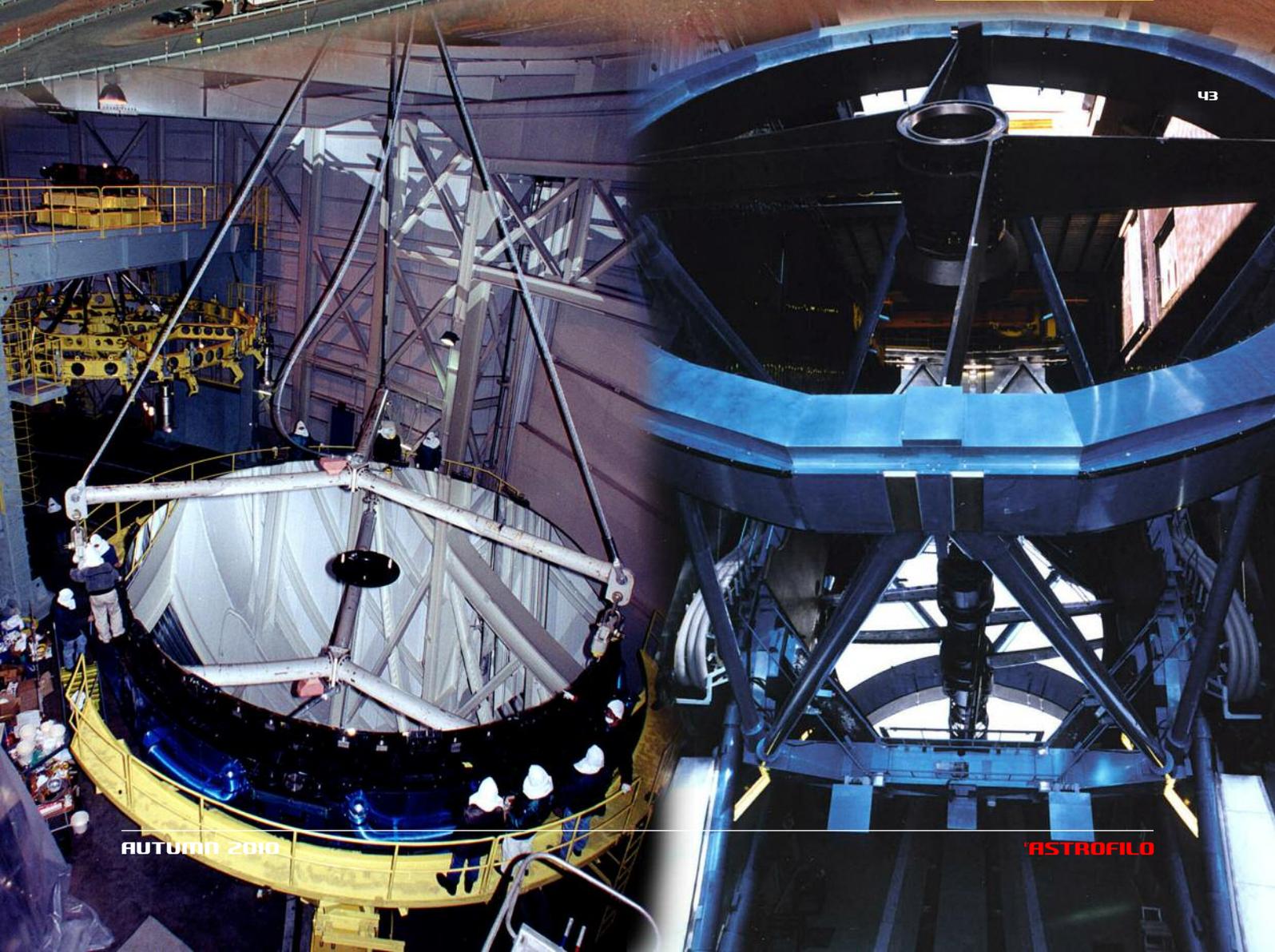
Subaru Telescope

Subaru, with its 8.2 metre mirror, is a Japanese telescope operated by the National Optical Astronomical Observatory of

42



Japan (NAOJ), located at an altitude of 4139 m at Mauna Kea Observatory in the Hawaiian islands (USA). Construction of the dome began in June 1992 on the summit of the vol-



cano, and the year after work started on the telescope itself, that was transported and mounted in 1998. First light was in 1999 and science verification of the instruments followed.

At the moment there are seven active instruments with one auxiliary instrument. The observational capabilities of the telescope in the optical and infrared have recently been increased

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with MOIRCS (Multi-Object Infrared Camera and Spectrograph), that began service in February 2006.

Subaru Telescope web site:
www.naoj.org

Nazionale Astro-
nomical Observa-
tory of Japan:
[www.nao.ac.jp/E/i
ndex.html](http://www.nao.ac.jp/E/index.html)

Credits: NAOJ,
Andrew X, E. Sas-
sone Corsi, F. Ber-
nardi, G. Galletta,
M. Clemens.

*Very Large
Telescope
8,2 metres x 4*

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Very Large Telescope

The Very Large Telescope (VLT) is a system of four optical reflecting telescopes, each with a primary mirror of 8.2 me-

tres, accompanied by four 1.8 m auxiliary telescopes (ATs). The VLT is part of the largest European astronomy organisation, the European Southern Observatory (ESO), and is located at Cerro Para-



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nal Observatory, at an altitude of 2635 metres in the Atacama desert, Chile. The four telescopes were christened with names in Mapudungun, the native Chilean language: Antu (UT1, the Sun), Kueyen

SI

(UT2, the Moon), Melipal (UT3, the Southern Cross) and Yepun (UT4, Venus). Each 8.2 metre mirror is so thin that it needs to be supported by 150 small pistons that allow it to maintain

the correct shape every time it is moved. The adaptive optics are of the last generation. The so-called MAD (MultiConiugate Adaptive Optics Demonstrator) system extends the



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corrected field of view to 15 arcseconds and was first installed on 25th March 2007 on UT3-Melipal. The telescopes can work together, in groups of two or three, to form a gigantic interfero-

meter, the Very Large Telescope Interferometer (VLTI), allowing for a resolution 25 times higher than possible with a single telescope. In May 1998 the first of the four telescopes, UT1-

REOSC
SAGEM

55

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Antu, started operation. The selection of the site was based on the lack of rain, the large number of clear nights each year, the high altitude and the distance from sources of light pollution.

Very Large Telescope web site:
www.eso.org/public/telesinstr/vlt.html.

Credits: ESO/H. H. Heyer, G. Altavilla, G. Galletta, G. Masi, E. Sassone Corsi.

Gemini North
and Gemini South
Telescopes
8.1 metres

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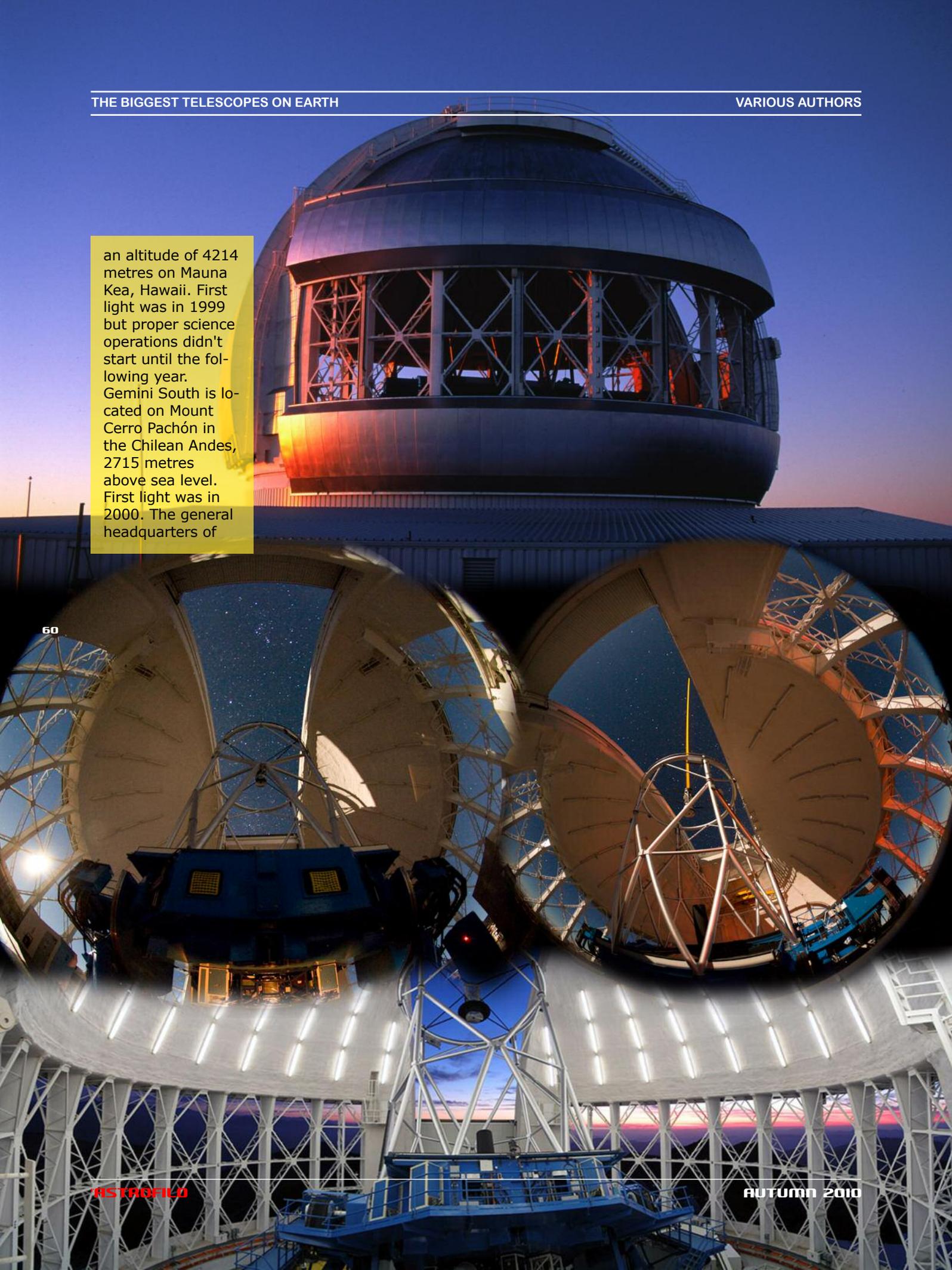
Gemini
North and
Gemini
South

Gemini North and Gemini South are two twin optical telescopes of 8.1 m diameter, one in each hemisphere, that between them can observe the entire sky. Both

telescopes are equipped with various instruments for observation at both optical and infrared wavelengths. Multiple instruments can be simultaneously mounted at the Cassegrain focus. Gemini North, also called the Frederick C. Gillett Telescope, is located at

an altitude of 4214 metres on Mauna Kea, Hawaii. First light was in 1999 but proper science operations didn't start until the following year. Gemini South is located on Mount Cerro Pachón in the Chilean Andes, 2715 metres above sea level. First light was in 2000. The general headquarters of

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both telescopes is the operations centre for the northern telescope in Hilo, at the University of Hawaii. The operations centre for the southern telescope is at the Cerro Tololo Inter-American Observatory (CTIO) in La Serena, Chile. The Gemini telescopes are operated by a consortium made

up of the United States, United Kingdom, Canada, Chile, Brasil, Argentina and Australia, and use the most advanced observational techniques such as adaptive optics, laser guide star and multi-object spectroscopy. The ventilation system and silver mirror surface aid observations at infrared

wavelengths. In December 2009 it was announced that the U.K. would leave the consortium in 2012 due to lack of funds.

Web site of the Gemini Observatory: www.gemini.edu.

Credits: F. Bernardi, M. Clemens
NOAO/AURA/NSF.