TELESCOPE TRAVEL GUIDE

THE BIG THREE, OLDEST FIRST

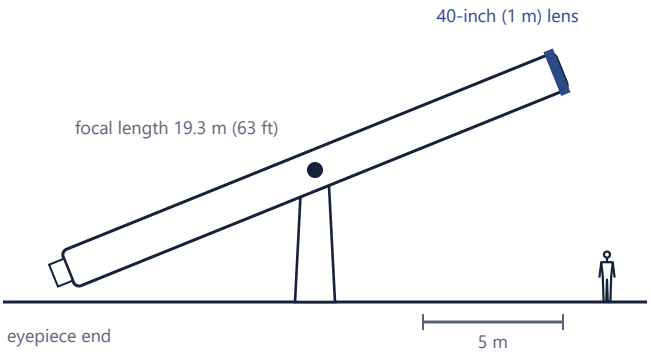
The largest refractor, the largest single-mirror reflector, and the largest space telescope. Then the major observatories of the world. The three big sketches use the **same scale**; the outline person is 1.8 m (5 ft 11 in) tall. Visiting an observatory counts toward requirement 8a.

1 · LARGEST REFRACTOR · 1897

Yerkes Observatory

Williams Bay, Wisconsin, a 50-acre campus on Geneva Lake · 334 m above sea level

- **How it started:** in 1892 astronomer George Ellery Hale learned that two 40-inch glass lens blanks were sitting unused. University of Chicago president William Rainey Harper backed him, and Chicago businessman Charles T. Yerkes paid. Building began in 1895, and it was dedicated on October 21, 1897.
- **The building:** designed by Henry Ives Cobb, covered with carved lions, animals and mythological figures. The grounds were planned by the Olmsted firm; today's arboretum follows their 1906 plan.
- **Why it matters:** often called the birthplace of modern astrophysics. The Astrophysical Journal was edited here until the 1960s, and a meeting of astronomers here in October 1897 led to the American Astronomical Society.



The Great Refractor: lens, tube and person to scale; mount simplified.

YERKES HAS THREE BIG TELESCOPES

40-INCH GREAT REFRACTOR · 1897

Officially the Sharon and Charles Angell Historic Refractor, and "the largest refracting telescope ever used for astronomy." The Alvan Clark & Sons lens is really 41 3/8 inches across and weighs 225 kg; it took 18 tries to cast the glass. Focal length 19.3 m (63 ft). The tube weighs 12,000 lb and the dome 280,000 lb. The Warner & Swasey mount was shown at the 1893 World's Columbian Exposition in Chicago. Electronic controls replaced the hand controls in the late 1960s. Restoration work: fall 2026.

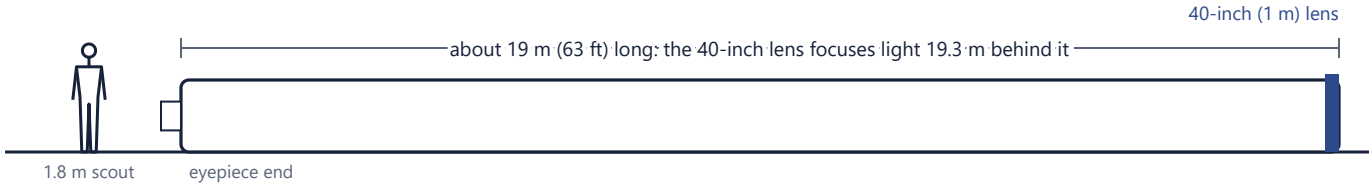
41-INCH REFLECTOR · 1967–68

A research telescope of the Ritchey-Chrétien design, with a mirror of Cer-Vit, a glass-ceramic that barely changes shape as it warms and cools. Its first instruments measured starlight and spectra, and it helped pioneer **adaptive optics**: bending a mirror many times a second to undo the twinkle the air adds to stars. It is not part of the public tours.

24-INCH REFLECTOR · 1964

A Cassegrain telescope by Boller & Chivens in one of the smaller domes on the east towers, ordered under director W. Albert Hiltner. Long used for visitor programs, it is the telescope the public looks through on today's "Exploring the Night Sky with the 24-inch Reflector" tour. It also fed real images to students through **Hands-On Universe** (next page).

HOW BIG IS THE 40-INCH? LAY IT DOWN NEXT TO A SCOUT



Tube length and person to scale (the tube is drawn on the ground; its width is simplified).

MORE TREASURES

- **The Bruce photographic telescope** (1904) took the long exposures for E. E. Barnard's atlas of the Milky Way and his catalog of dark nebulae.
- **The Snow Solar Telescope** started at Yerkes and moved to California in 1904.
- **About 180,000 glass plates:** photographs and spectra of the sky from 1889 to 2002, kept at Yerkes.
- **Asteroids named for it:** 990 Yerkes, 1024 Hale, 992 Swasey and 991 McDonalda.

People, discoveries, and how to visit

WHO WORKED HERE AND WHAT THEY FOUND

1897	**George Ellery Hale** opens Yerkes. He invented the spectroheliograph for photographing the Sun, then founded Mount Wilson Observatory and planned Palomar's 200-inch.
1900s	**E. E. Barnard** photographs the Milky Way; his niece and assistant **Mary Ross Calvert** worked as a computer and astrophotographer from 1905 to 1946. **S. W. Burnham**, a court reporter by day, is credited with 1,340 double stars.
1914–17	**Edwin Hubble** is a graduate student here. Later he showed there are other galaxies and that the universe is expanding.
1921	**Otto Struve** arrives, a refugee from the Russian Revolution; he later became director.
1936–50	**Subrahmanyan Chandrasekhar** works here; Nobel Prize in Physics, 1983. NASA's Chandra X-ray Observatory is named for him.
1943	**William W. Morgan**, Philip Keenan and Edith Kellman begin the MKK system for sorting stars by their spectra, still used today.
1944	**Gerard Kuiper** finds that Saturn's moon Titan has an atmosphere. In 1951 he proposed the icy belt beyond Neptune now called the Kuiper Belt.
1946–54	**Nancy Grace Roman** studies here; she became NASA's first Chief of Astronomy.
1951	**Morgan**, with Donald Osterbrock and Stewart Sharpless, discovers the Milky Way's spiral arms.
1950s	**Margaret Burbidge** (here 1951-53 and 1957-62) helps show in 1957 that most heavy elements are made inside stars. **Carl Sagan** is a graduate student here, 1956-60.

1921: ALBERT EINSTEIN VISITS

Einstein came to Yerkes in May 1921, during his first trip to the United States, and was photographed in front of the 40-inch. Why would the scientist who explained gravity want to see a telescope? His theory predicted that the Sun's gravity bends starlight, and eclipse photographs in 1919 had just shown that it does. Telescopes were how his ideas got tested.

HANDS-ON UNIVERSE

A program that lets students anywhere request observations, download real telescope images, and measure them with image software. Astrophysicist **Carl Pennypacker** of Lawrence Berkeley Laboratory and UC Berkeley leads it, and teachers and students using it have discovered supernovae. At Yerkes, educator **Vivian Hoette** ran the program on the 24-inch reflector, taking real images for students around the world (she and Pennypacker wrote about it together in 1996). One of our own leaders worked for her there.

PLUTO: FROM OLD GLASS TO NEW HORIZONS

In 1909 a Yerkes photograph caught Pluto, 21 years before Clyde Tombaugh discovered it at Lowell Observatory in 1930; nobody noticed. Nearly a century later, NASA borrowed glass plates from the Yerkes archive, taken in the years before Pluto's discovery, to help pin down Pluto's path for the New Horizons mission: the more years of positions you have, the better you know an orbit. **One of our own leaders, who worked at Yerkes, pulled those plates and handed them to NASA.** New Horizons launched January 19, 2006, flew about 12,500 km above Pluto on July 14, 2015, and sent back the famous "heart": a nitrogen-ice glacier about 1,000 km wide.

LIGHTS, CAMERA, YERKES

Scenes for the 1996 action movie **Chain Reaction**, starring Keanu Reeves, Morgan Freeman and Rachel Weisz, were filmed at Yerkes. In the story the heroes hide out at a Wisconsin observatory. The movie also filmed at the University of Chicago, Argonne National Laboratory and Chicago's Museum of Science and Industry.

IS IT RETIRED? VISITING TODAY. The University of Chicago ran Yerkes for 121 years and closed it on October 1, 2018. The Yerkes Future Foundation, a nonprofit started by local residents, took ownership on May 1, 2020, restored the building and grounds, and reopened in 2022. It is no longer a university research center, but it now has its own staff astronomer, runs on solar power, and is by far the closest of the big three to Chicago.

- **Where:** 373 W Geneva St., Williams Bay, WI 53191 · (262) 245-5555 · yerkesobservatory.org
- **Free:** the grounds, arboretum and 4+ miles of trails, sunrise to sunset, no ticket. Leashed pets welcome outside.
- **Inside: ticketed tours only.** Tickets go on sale 2 months ahead and are non-refundable. Space & Spaces Tour (1.5 hr, ages 5+): stand beneath the great telescope. Director's Hidden Spaces (ages 14+, usually Friday mornings): includes what Yerkes calls the world's largest indoor elevator. Frostlights: a winter light show in the dome, all ages.
- **Look through the telescopes:** Exploring the Night Sky (2 hr, ages 13+, 12 guests, March to November): the 40-inch when skies are clear, $140 adults, $85 ages 13-18. The 24-inch version is $100. Both sold out for 2026.
- **For troops:** Yerkes offers Guided Educational Visits for scouts and youth groups, including badge work: a 1.5 hour staff-led tour plus solar observing or a hands-on activity. Book through yerkesobservatory.org/contact or by phone.
- **Know before you go:** the dome is not heated, so dress warmly; it is 26 stairs up; there is no food service. Prices and dates are as listed in November 2026 and change, so check the website.

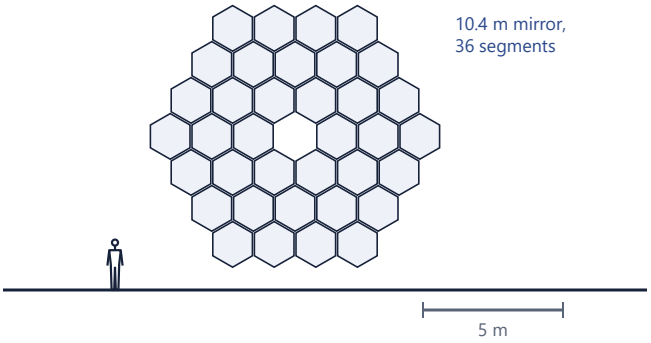
2 · LARGEST SINGLE-MIRROR REFLECTOR · 2009

Gran Telescopio Canarias (GTC)

Roque de los Muchachos Observatory, La Palma, Canary Islands, Spain · about 2,300 m (sources differ: 2,267 to 2,396 m)

- **The mirror:** 10.4 m across, made of 36 hexagonal segments that computer-controlled actuators keep aligned (active optics). Collecting area 78.5 m².
- **Timeline:** first light July 13, 2007 with 12 segments; science from May 2009; opened by King Juan Carlos I of Spain on July 24, 2009. Seven years to build, 130 million euros.
- **Who uses it:** Spain 90%, Mexico 5%, the University of Florida 5%. Cameras and spectrographs for visible and near-infrared light.
- **Problem it solves:** the bigger the mirror, the fainter and farther the objects it can study. La Palma is one of the best observing sites in the Northern Hemisphere, second only to Mauna Kea.
- **Close rivals:** the twin Keck telescopes in Hawaii (10 m each, also 36 segments). The Large Binocular Telescope in Arizona combines two 8.4 m mirrors to act like 11.9 m, but it is not a single mirror. The Extremely Large Telescope (39 m, 798 segments) is being built in Chile, first light planned for 2029.

VISIT: a road climbs to the summit (2,426 m), and the Roque de los Muchachos Visitor Centre opened in December 2021. Check the observatory's website for tours before you go.



Mirror seen face-on, to scale with the person.

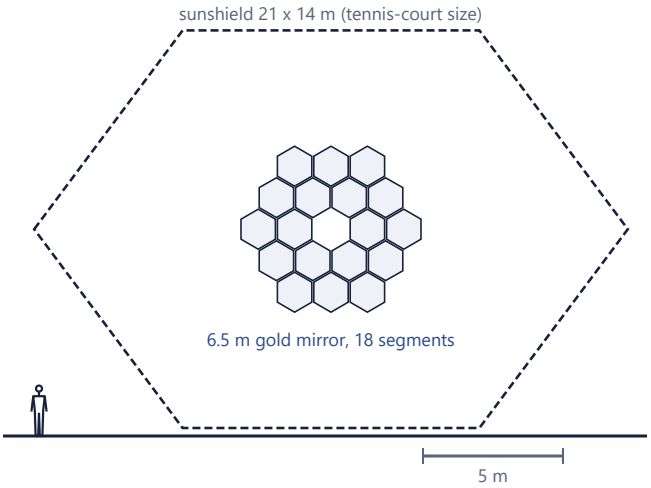
3 · LARGEST SPACE TELESCOPE · 2021

James Webb Space Telescope

In orbit around the Sun-Earth L2 point, about 1.5 million km from Earth

- **The mirror:** 6.5 m across, 18 hexagonal beryllium segments coated with a gold layer about 100 nanometers thick: only about 48 grams of gold in all. It is 2.7 times wider than Hubble's mirror, with about six times the collecting area.
- **The sunshield:** 21.2 m by 14.2 m, the size of a tennis court: five layers of aluminum-coated film that keep the telescope cold enough to see infrared.
- **Launch:** December 25, 2021, on an Ariane 5 rocket from Kourou, French Guiana. It reached L2 on January 24, 2022. A NASA, European (ESA) and Canadian (CSA) mission with 14 countries.
- **Problem it solves:** it sees infrared light (0.6 to 28.5 microns), which passes through dust clouds and carries the light of the very first galaxies, stretched into infrared by the expanding universe.
- **Discoveries:** its first images in July 2022 (the Carina Nebula "Cosmic Cliffs", Stephan's Quintet, the Southern Ring Nebula, a deep field full of galaxies, and water in the air of planet WASP-96b). In 2024 it found JADES-GS-z14-0, a galaxy seen as it was about 290 million years after the Big Bang.
- **Its older cousin:** Hubble, 2.4 m mirror, launched April 24, 1990 on Space Shuttle Discovery, circles Earth about 480 km (300 miles) up every 95 minutes.

VISIT: you can't, it is 1.5 million km away. Its pictures are free at science.nasa.gov/mission/webb. Webb is run from the Space Telescope Science Institute in Baltimore, and its building was managed by NASA's Goddard Space Flight Center in Greenbelt, Maryland, which has a visitor center (check before you go).



Mirror and sunshield shown flat, to scale. In space the mirror stands above the shield.

TELESCOPE TRAVEL GUIDE

MAJOR OBSERVATORIES OF THE WORLD

Each card: where it is, height above sea level and opening year, its biggest instruments, why it matters, and how to visit. Opening hours and tour rules change, so check each observatory's own website before you go.

UNITED STATES

McDonald Observatory

Fort Davis, Texas · 2,077 m · 1933

Big glass: Hobby-Eberly Telescope, 10 m effective (91 mirror segments); the 2.1 m Otto Struve Telescope (1939).

History: Banker William J. McDonald left about $1 million to the University of Texas. Yerkes' owner, the University of Chicago, ran it until the 1960s; Gerard Kuiper found the moons Miranda (Uranus, 1948) and Nereid (Neptune, 1949) with the 2.1 m.

Today: Dark energy research and bouncing lasers off the Moon.

Visit: Frank N. Bash Visitors Center: daily solar viewing and evening star parties.

Kitt Peak National Observatory

Near Tucson, Arizona · 2,096 m · 1960

Big glass: Over twenty telescopes, including the Mayall 4 m and the WIYN 3.5 m.

History: On land leased from the Tohono O'odham Nation. In 1976 the Mayall found methane ice on Pluto.

Today: DESI maps millions of galaxies to study dark energy; NEID hunts for planets around other stars.

Visit: Reopened to the public in 2023: daytime tours and nightly observing programs.

Lowell Observatory

Flagstaff, Arizona · 2,210 m · 1894

Big glass: The 24-inch Clark refractor (1896) and the 4.3 m Lowell Discovery Telescope.

History: Founded by Percival Lowell. **Clyde Tombaugh discovered Pluto here on February 18, 1930.** V. M. Slipher's measurements of galaxies speeding away helped lead to the discovery that the universe is expanding.

Today: Planets around other stars, and watching for asteroids that come near Earth.

Why here: Height, dark skies, and the railroad nearby.

Visit: Tours, the Clark refractor and the Astronomy Discovery Center (2024).

Very Large Array (VLA)

Near Socorro, New Mexico · 2,124 m · 1980

Big glass: 28 radio dishes, 25 m each, on a Y-shaped track with arms 21 km long.

History: Caught Voyager 2's signals at Neptune in 1989; starred in the movie Contact (1997).

Problem it solves: Spread-out dishes work together like one giant radio telescope to see fine detail: black holes, planet-forming disks, the center of our galaxy.

Visit: Visitor center with a small museum and a self-guided walking tour.

Palomar Observatory

San Diego County, California · 1,712 m · 200-inch first light 1949

Big glass: The 200-inch (5.1 m) Hale Telescope, the world's largest from 1949 to 1975; Edwin Hubble was its first user.

Discoveries: Dwarf planets Eris and Sedna, more than 100 supernovae by Fritz Zwicky, and Comet Shoemaker-Levy 9 (1993).

Today: Caltech research every clear night.

Visit: Self-guided 200-inch tours daily; guided weekend tours April to October.

Mount Wilson Observatory

Above Pasadena, California · 1,742 m · 60-inch 1908, 100-inch 1917

Big glass: The 100-inch Hooker Telescope, the world's largest from 1917 to 1949.

Discoveries: **Edwin Hubble** used it to prove the Andromeda nebula is a separate galaxy (1923 to 1924) and, in 1929, working with Milton Humason, that the universe is expanding.

Why here: Unusually steady air over Los Angeles. Today's city lights limit deep-sky research.

Visit: Ticketed public nights looking through the 100-inch; group nights on the 60-inch.

Lick Observatory

Mount Hamilton, near San Jose, California · 1,283 m · 1888

Big glass: The 36-inch Great Lick Refractor, the 3 m Shane reflector and the Automated Planet Finder.

History: Funded by James Lick; the world's first permanently occupied mountain-top observatory. E. E. Barnard discovered Jupiter's moon Amalthea here in 1892.

Why here: Calm air; low coastal clouds fill the valley below and hide the city lights.

Visit: Check the observatory's website.

Green Bank Observatory

West Virginia · 1956

Big glass: The 100 m Robert C. Byrd Green Bank Telescope (2000).

History: Project Ozma (1960) was the first radio search for signals from other civilizations. Found the most massive neutron star known (2019).

Why here: The National Radio Quiet Zone (1958): about 13,000 square miles where radio transmitters are limited. Cell phones are very restricted near the telescope.

Visit: About 40,000 visitors a year.

Mauna Kea Observatories

Island of Hawaii · 4,205 m · first telescope 1970

Big glass: The twin 10 m Keck telescopes (36 segments each), the 8.2 m Subaru and the 8.1 m Gemini North: 13 facilities in all.

Why here: Above most of the air's water vapor: dry, dark and clear. Gerard Kuiper scouted it for infrared astronomy.

History: Many Native Hawaiians consider the mountain sacred, and new telescopes, like the proposed Thirty Meter Telescope, have been controversial.

Visit: Visitor Information Station at 9,200 ft; stop at least 30 minutes to get used to the thin air.

Arecibo Observatory

Puerto Rico · 1963 to 2020

Big glass: A 305 m dish built in a natural sinkhole: the world's largest single dish for 53 years, until FAST.

History: On November 16, 1974 it beamed the **Arecibo message**, 1,679 bits designed by Frank Drake and colleagues, toward the star cluster M13. After cables snapped in 2020, the platform fell on December 1, 2020; no one was hurt.

Today: Not rebuilt; becoming an education center.

Visit: The Angel Ramos Foundation Visitor Center stayed open.

CHILE: THE SOUTHERN SKY

Paranal Observatory (ESO)

Atacama Desert, Chile · 2,635 m · 1999

Big glass: The Very Large Telescope: four 8.2 m telescopes plus four 1.8 m helpers that can work together as one.

Today: The Southern Hemisphere's largest visible and infrared observatory. The 39 m Extremely Large Telescope is being built 20 km away.

Visit: Check ESO's website.

La Silla Observatory (ESO)

Chile · 2,400 m · 1969

Big glass: The ESO 3.6 m with the HARPS planet finder, and the 3.5 m New Technology Telescope, which pioneered active optics (1989).

Discoveries: Small planets around other stars, including the Gliese 581 system.

Why here: Dry, far from lights and dust: some of the darkest skies on Earth.

Visit: Check ESO's website.

Cerro Tololo Inter-American Observatory

Chile · 2,207 m · 1965

Big glass: The 4 m Victor M. Blanco Telescope (1974) and the 4.1 m SOAR telescope nearby.

Today: Run with Kitt Peak by the U.S. NOIRLab; a home base for southern-sky research.

Visit: Check the observatory's website.

Vera C. Rubin Observatory

Cerro Pachon, Chile · about 2,670 m · first images 2025

Big glass: An 8.4 m telescope with a 3.2-gigapixel camera, the largest camera ever built.

Problem it solves: It photographs the whole southern sky every few nights for ten years: a movie of the universe that should catch over 5 million asteroids and about 20 billion galaxies.

Visit: Check the observatory's website.

ALMA

Chajnantor plateau, Chile · about 5,000 m · 2013

Big glass: 66 radio antennas (fifty 12 m) that can be moved and spread kilometers apart.

Discoveries: Rings in the planet-forming disk around HL Tauri (2014), and part of the first picture of a black hole (2019).

Why here: Very high and very dry, so the air adds less noise.

Visit: Public visits were paused in 2020; check before you go.

EUROPE

Royal Observatory Greenwich

London, England · 1675

History: Founded by King Charles II to help sailors solve the longitude problem: knowing how far east or west they were. In 1884 its meridian became the world's **Prime Meridian**, longitude 0.

Today: A museum and planetarium. A time ball drops at 1:00 pm every day, and a green laser marks the old meridian at night.

Visit: Stand on the Prime Meridian line, one foot in each hemisphere.

Jodrell Bank Observatory

Cheshire, England · 1945

Big glass: The 76 m Lovell Telescope (1957), the world's largest steerable dish when built.

History: Bernard Lovell moved war-surplus radar here, away from the noise of Manchester's trams. In October 1957 it was the only telescope able to track Sputnik's rocket by radar. UNESCO World Heritage Site (2019).

Visit: Jodrell Bank Discovery Centre and a path around the telescope.

Roque de los Muchachos Observatory

La Palma, Canary Islands, Spain · 1985

Big glass: The Gran Telescopio Canarias (see the big three), the 4.2 m William Herschel and the 2.5 m Isaac Newton telescopes.

History: The Isaac Newton Telescope was moved here from cloudy England. One of the best northern sites, second to Mauna Kea.

Visit: Visitor Centre opened December 2021.

RUSSIA

Special Astrophysical Observatory

North Caucasus mountains, Karachay-Cherkessia, Russia · formed 1966

Big glass: **BTA-6**: a 6 m mirror weighing 42 tonnes in a 48 m dome, at 2,070 m. First light December 1975; the world's largest telescope until Keck in Hawaii passed it (about 1990 to 1993).

Lesson learned: The first mirror cracked because the glass cooled too fast, and the second had flaws that crews covered with black cloth. A third mirror (1978) fixed the worst problems.

Also here: **RATAN-600**, a radio telescope: a ring 576 m across made of 895 reflecting panels, first light 1974. It studies the Sun's corona and has joined searches for signals from other civilizations.

Why here: The old observatory at Pulkovo sits only 75 m above sea level, so 16 expeditions searched the USSR for a better site.

Visit: Check before you go.

Pulkovo Observatory

Near St. Petersburg, Russia · 1839

History: Founded by Friedrich Georg Wilhelm von Struve. Its 30-inch refractor (1885) was the biggest working refractor in the world until Lick's 36-inch. Its meridian was the zero line for Russian maps.

War: Bombing and shelling in the Siege of Leningrad (1941 to 1944) destroyed every building, but the main instruments, including the 30-inch lens, were saved. It reopened in 1954.

Today: The main observatory of the Russian Academy of Sciences, part of a UNESCO World Heritage Site.

Visit: Check before you go.

Baikal Astrophysical Observatory

Listvyanka, on Lake Baikal near Irkutsk, Siberia · about 670 m · 1980 · run by the Institute of Solar-Terrestrial Physics

Big glass: The **Large Solar Vacuum Telescope**, with a 76 cm (30-inch) lens: the largest solar refracting telescope in Eurasia. A 1 m flat mirror (a siderostat) at the top of a slanted tower about 25 m tall follows the Sun and sends its light down a tube pumped empty of air into a lab below, so no heat shimmer inside can blur the picture.

Why here: In summer the ice-cold lake soaks up heat from the air above it, calming the rising warm air that usually blurs the daytime Sun. Approved in 1978, finished in 1980.

Today: Sunspots, solar flares and the Sun's magnetic fields, plus daily watch for space weather that can upset satellites, power grids and radio. Smaller telescopes film the whole Sun in hydrogen-alpha and calcium light.

Nearby: The same institute runs an 80 cm solar telescope at about 2,000 m in the Sayan Mountains and the Siberian Radioheliograph (since 1983, upgraded 2017), which maps the Sun in microwaves.

Been there: One of our own leaders has been inside the Baikal solar telescope.

Visit: Daytime tours have shown live, magnified projections of sunspots in the telescope lab, and the hilltop looks over the source of the Angara River, the only river flowing out of Baikal. Check before you go.

AFRICA, AUSTRALIA AND ASIA

South African Astronomical Observatory and SALT

Sutherland, South Africa · SAAO 1972, SALT 2005

Big glass: SALT, the Southern African Large Telescope: 91 segments, 9.2 m effective, the largest optical telescope in the Southern Hemisphere.

History: SAAO grew from the Royal Observatory at the Cape of Good Hope (1820). A 2007 law protects the dark Karoo skies.

Visit: About 14,000 visitors a year (2018 figure).

Siding Spring Observatory

Near Coonabarabran, New South Wales, Australia · site chosen 1962

Big glass: The 3.9 m Anglo-Australian Telescope (1974) and SkyMapper; over 60 telescopes.

Why here: Canberra's city lights had swamped Mount Stromlo, so astronomers moved to these dark, clear skies.

Visit: Visitor gallery, school-holiday tours and an October open day.

Parkes Observatory (Murriyang)

New South Wales, Australia · 1961

Big glass: A 64 m radio dish.

History: Nine minutes into the Apollo 11 moonwalk broadcast, NASA switched to Parkes for the rest of the 2.5 hours. It found the first fast radio burst. Fun fact: mystery signals called perytons were the staff microwave oven (2015).

Visit: Visitors Centre with exhibits and a 3D theater.

FAST

Guizhou, China · completed 2016

Big glass: A 500 m radio dish in a natural sinkhole, the world's largest single dish since 2016 (it uses a 300 m circle at a time).

Discoveries: More than 1,000 pulsars by November 2024; it also searches for signals from other civilizations.

Why here: Radio quiet: about 9,110 people were relocated, and no phones are allowed within 5 km.

Visit: Check before you go.

Facts checked 2026-11-12 against Wikipedia, NASA and yerkesobservatory.org, plus first-hand notes from our leaders; where sources disagree (some altitudes and dates), this guide rounds or gives the range. Yerkes is covered in the big three.