2 THE VIEW FROM THE GROUND

FIGURE 13: THE AUSTRALIAN RADIO TELESCOPE ARRAY

This beautiful image shows parts of the Australia Telescope Compact Array (ATCA) near the town of Narrabri in rural New South Wales. It was taken just before sunrise with Mercury, Venus and the Moon all appearing close together in the sky behind the array. Mercury is the highest of the three bright celestial beacons. The ATCA consists of six radio telescopes, each one larger than a house. Sometimes combined with more distant telescopes — like the 64-metre Parkes dish — they can form one of the highest resolution measurement devices in the world.

Astronomy is an observational science. Apart from the use of space probes in the Solar System, it is not possible to carry out experiments *in situ*, and information must be gleaned from light signals collected by telescopes and measured with instruments such as cameras and spectrometers, which spread out the light into its constituent wavelengths and allow a closer study. Most of the telescopes in existence observe the heavens from the ground — often from remote mountain tops to get above as much of the Earth's disturbing atmosphere as possible. But ground-based telescopes are much more than the well known visible-light telescopes that collect light from remote stars and galaxies with gigantic mirrors...

“Galileo pioneered the scientific method by thoroughly documenting all the new astronomical bodies and phenomena he saw with the telescope”

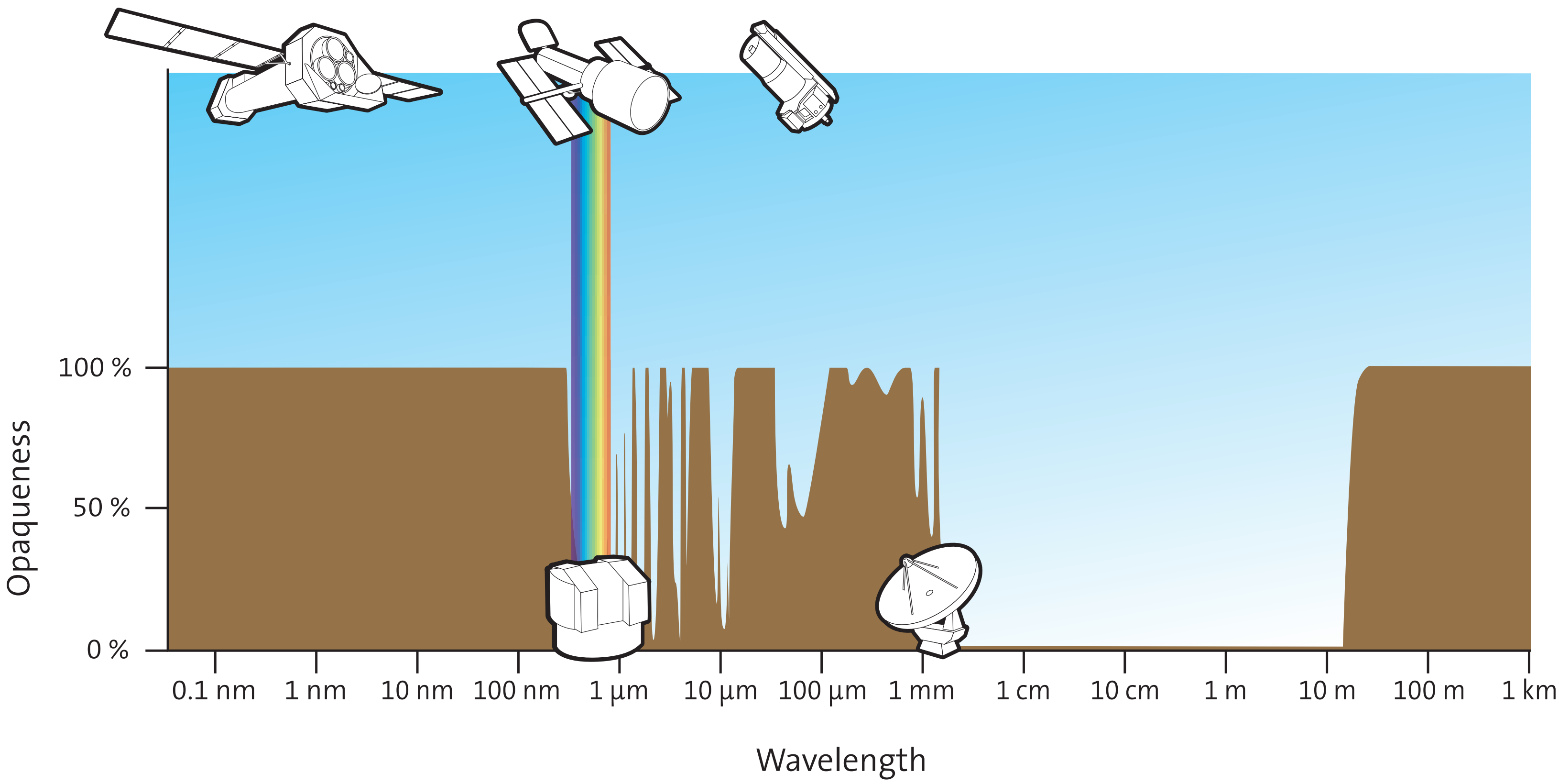
The telescope was invented in the early 17th century by Dutch spectacle makers and used for astronomical research for the first time by the Italian Galileo Galilei in 1609. Galileo pioneered the scientific method by thoroughly documenting all the new astronomical bodies and phenomena he saw with the telescope: craters on the Moon, Jupiter’s moons and spots on the Sun.

Since Galileo, thousands of observatories have been built around the world, and, since the 1960s, also in space. There are many advantages to be gained by observing from space (see Chapter 3), but it is expensive to launch telescopes and, with the notable exception of the Hubble Space Telescope, it is not possible to repair and upgrade them once they are there. Consequently, good sites on the ground are very attractive places to build large and powerful telescopes. These can then be continuously upgraded as new technology becomes available. Ground-based telescopes, working at visible, infrared and radio wavelengths, are forefront devices that usually work to complement the expensive, and usually smaller, space telescopes.

Atmospheric obstacles

Telescopes located on the ground must cope with the distorting and **absorbing/scattering** effects of the atmosphere. Even at the most carefully chosen locations, the atmosphere is completely or partially opaque over large tracts of the **electromagnetic spectrum** (see Figure 14).

From the highest energy gamma rays, right through the X-ray band to the near-ultraviolet, at a wavelength of around 300 nm, the atmosphere completely absorbs radiation and astronomers are blind from the ground. The visible-light band is relatively transparent, especially from high-altitude sites, and there are a number of useable windows in the infrared extending up to wavelengths of about 20 micrometres. Then comes a long stretch of the spectrum, covering the far-infrared, up to wavelengths just short of 1 mm,



where all radiation is again absorbed except in a few "holes" where the atmosphere is fairly transparent. In the so-called millimetre and sub-millimetre part of the spectrum, the principal absorber of light is water, and in this region observations can only be carried out effectively at very high, dry sites like the 5000-metre high Chajnantor plain on the Northern Chilean altiplano, the site of ALMA. For longer radio wavelengths, from around 1 centimetre upwards, the atmosphere is very transparent, although it is still capable of distorting radio "images" when conditions are not optimal. The Earth's ionosphere finally cuts in at wavelengths of around 20 metres. As well as absorbing and scattering light, the atmosphere will radiate light during the night when it is not illuminated by the Sun. In the near-infrared, certain gas molecules, notably the combination of a single oxygen and a hydrogen atom (the so-called OH radical), emit strongly, making the sky appear quite bright. At longer infrared wavelengths, the atmosphere is bright simply because it emits heat radiation.

Not only does atmospheric transmission reduce or block the radiation coming from astronomical objects, but the turbulence, all too familiar to any airline passenger, bends the incoming light through small angles that change continuously with time and position on the sky. Astronomers call this atmospheric phenomenon "seeing". The quality of the seeing usually seriously limits the amount of fine detail that can be observed by ground-based telescopes in stars and galaxies (also known as the **resolution**). To com-

FIGURE 14: THE OPAQUENESS OF THE ATMOSPHERE

The opaqueness of the atmosphere measured on a scale from 0% to 100% (completely opaque) with some major astronomical telescopes. Three space observatories are seen at the top (from left): the XMM-Newton telescope, the Hubble Space Telescope and the Spitzer Space Telescope. At the bottom two ground-based telescopes (VLT and ALMA) are seen in two of the "windows" in the atmosphere where light can reach the Earth's surface.