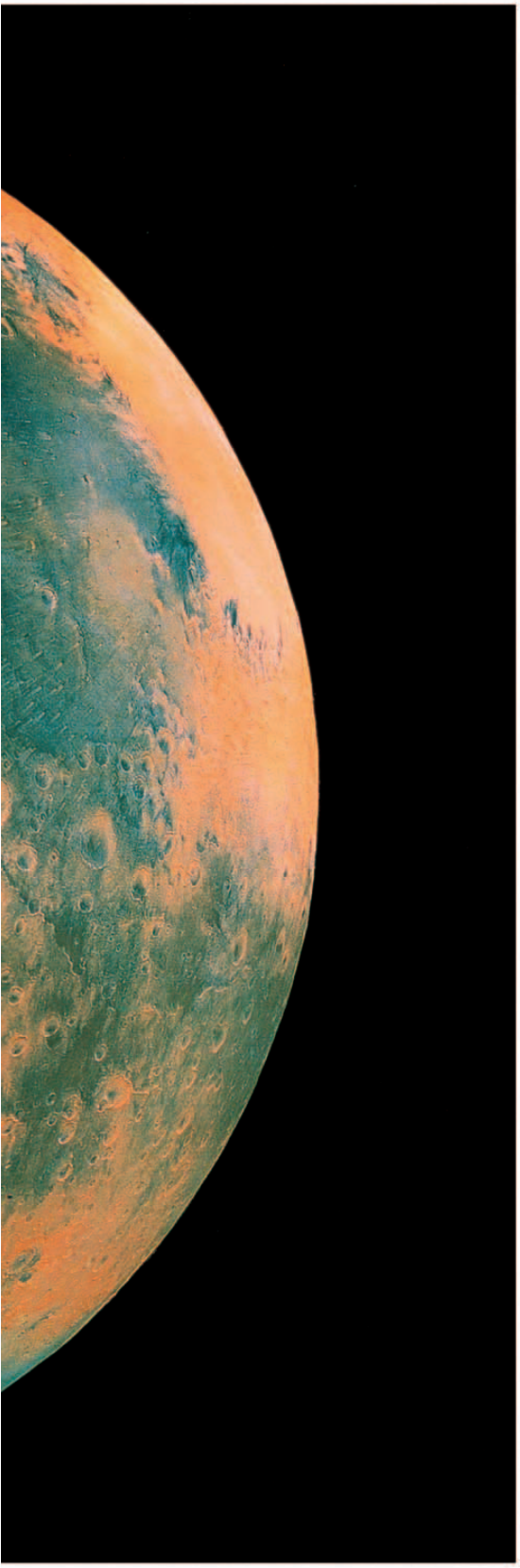
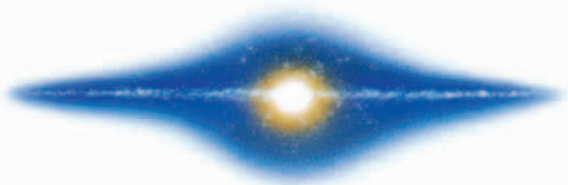
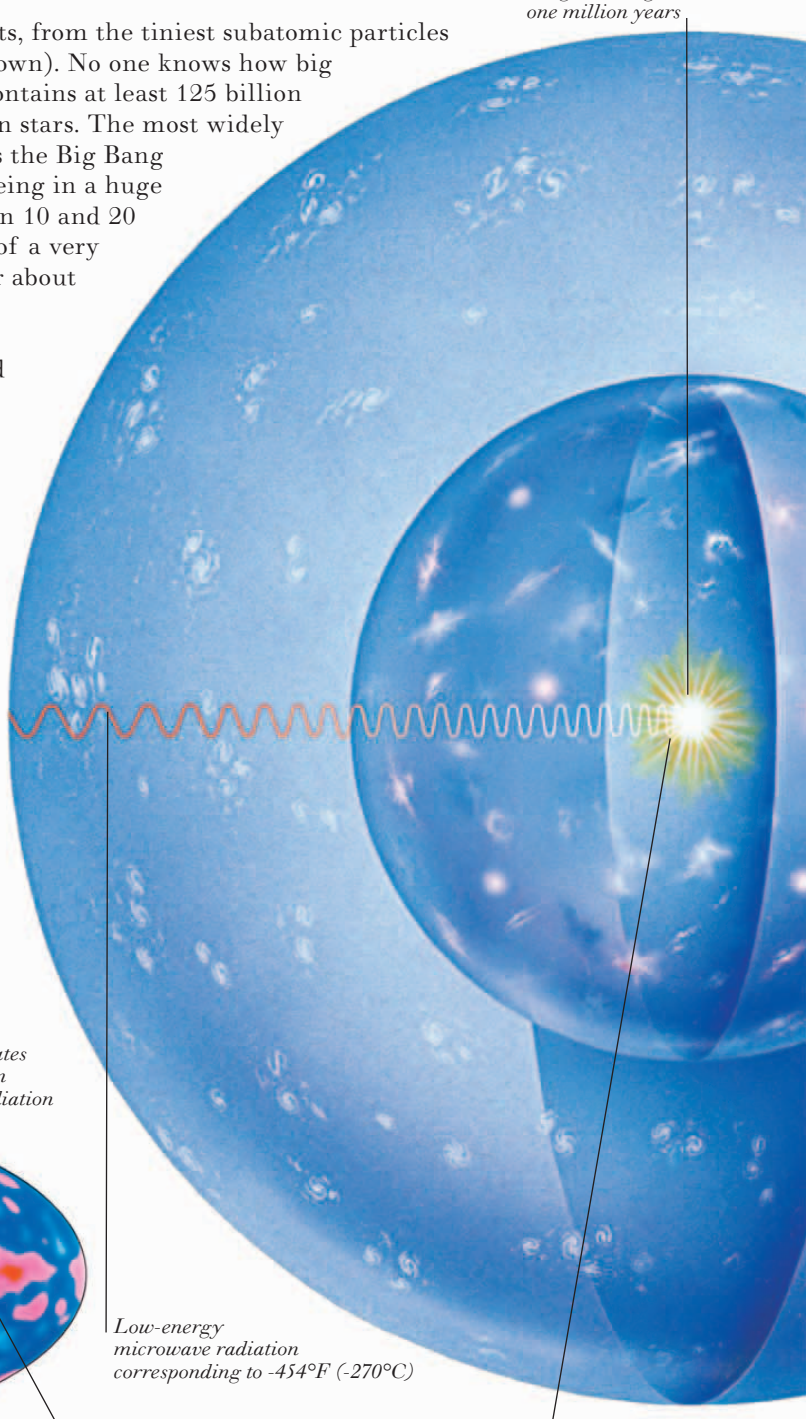


The Universe

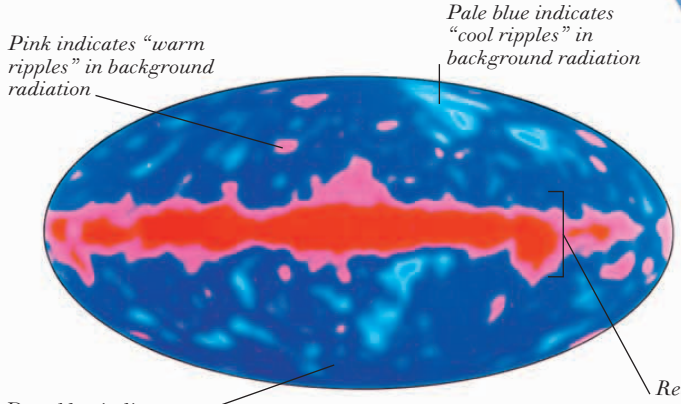


Anatomy of the universe

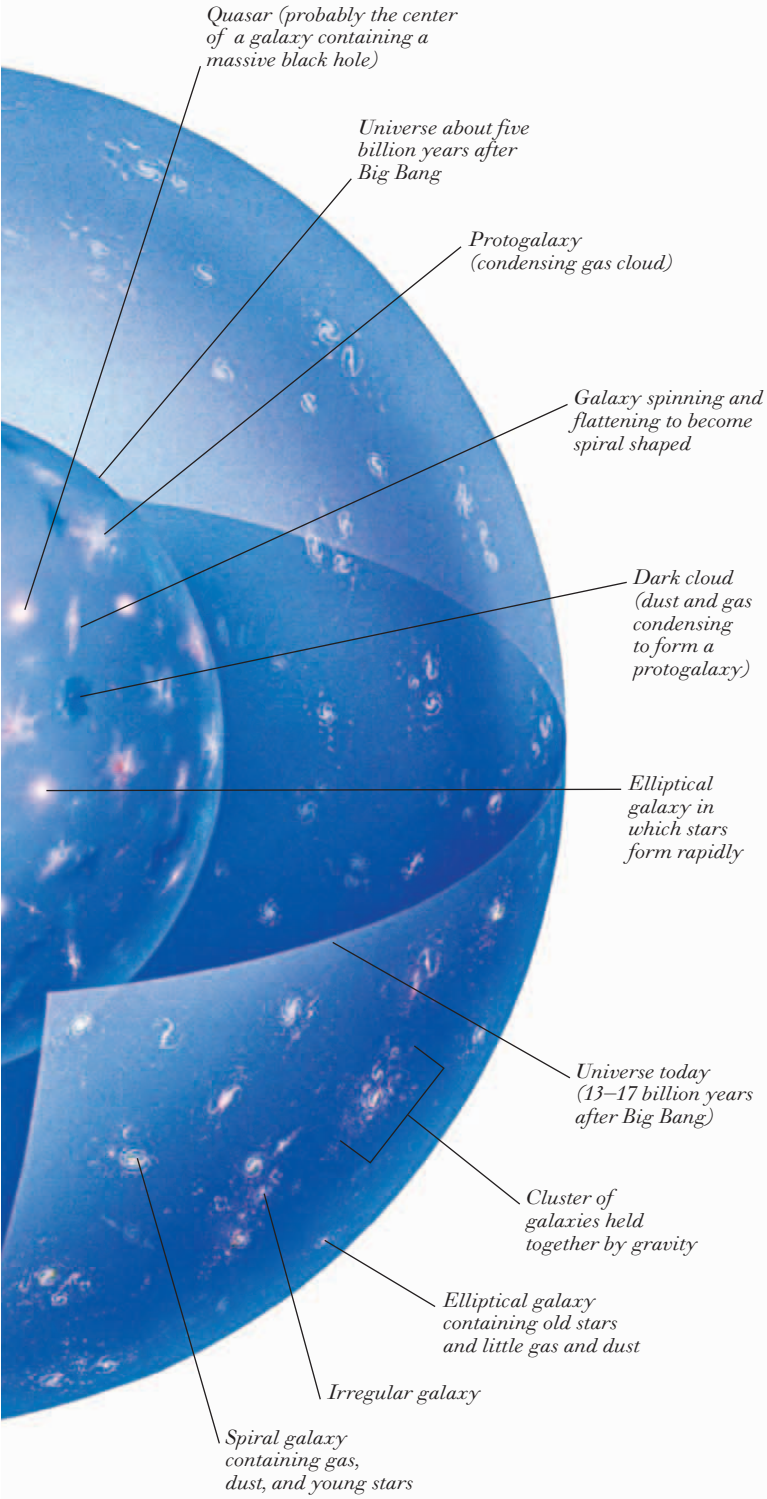
THE UNIVERSE CONTAINS EVERYTHING that exists, from the tiniest subatomic particles to galactic superclusters (the largest structures known). No one knows how big the universe is, but astronomers estimate that it contains at least 125 billion galaxies, each comprising an average of 100 billion stars. The most widely accepted theory about the origin of the universe is the Big Bang theory, which states that the universe came into being in a huge explosion—the Big Bang—that took place between 10 and 20 billion years ago. The universe initially consisted of a very hot, dense fireball of expanding, cooling gas. After about one million years, the gas began to condense into localized clumps called protogalaxies. During the next five billion years, the protogalaxies continued condensing, forming galaxies in which stars were being born. Today, billions of years later, the universe as a whole is still expanding, although there are localized areas in which objects are held together by gravity; for example, many galaxies are found in clusters. The Big Bang theory is supported by the discovery of faint, cool background radiation coming evenly from all directions. This radiation is believed to be the remnant of the radiation produced by the Big Bang. Small "ripples" in the temperature of the cosmic background radiation are thought to be evidence of slight fluctuations in the density of the early universe, which resulted in the formation of galaxies. Astronomers do not yet know if the universe is "closed," which means it will eventually stop expanding and begin to contract, or if it is "open," which means it will continue expanding forever.



FALSE-COLOR MICROWAVE MAP OF COSMIC BACKGROUND RADIATION

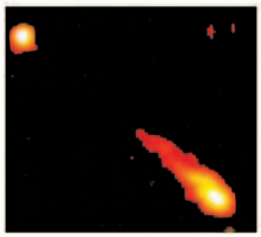


ORIGIN AND EXPANSION OF THE UNIVERSE



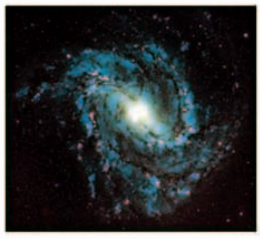
OBJECTS IN THE UNIVERSE

CLUSTER OF GALAXIES IN VIRGO



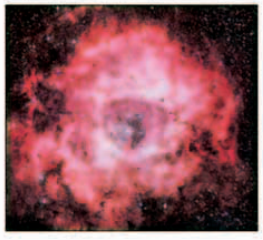
FALSE-COLOR IMAGE OF 3C273 (QUASAR)

NGC 4406 (ELLIPTICAL GALAXY)

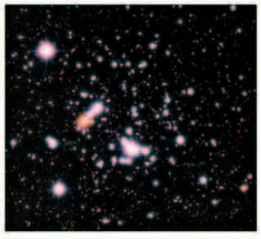


NGC 5236 (BARRED SPIRAL GALAXY)

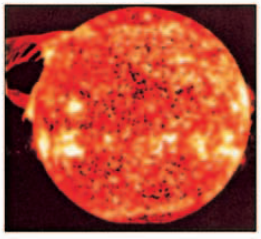
NGC 6822 (IRREGULAR GALAXY)



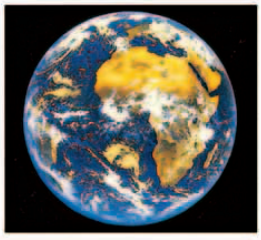
THE ROSETTE NEBULA (EMISSION NEBULA)



THE JEWEL BOX (STAR CLUSTER)



THE SUN (MAIN SEQUENCE STAR)



EARTH

THE MOON

Galaxies

SOMBRERO, A SPIRAL GALAXY

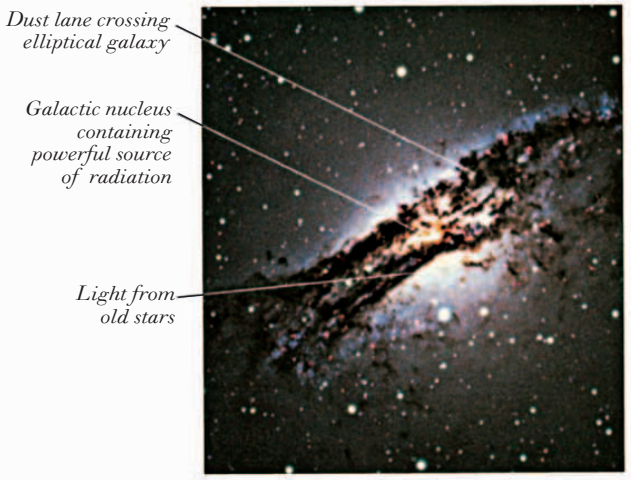
A GALAXY IS A HUGE MASS OF STARS, nebulae, and interstellar material. The smallest galaxies contain about 100,000 stars, while the largest contain up to 3 trillion stars. There are three main types of galaxy, classified according to their shape: elliptical, which are oval shaped; spiral, which have arms spiraling outward from a central bulge (those whose arms spiral from a bar-shaped bulge are called spirals); and irregular, which have no obvious shape. Sometimes, the shape of a galaxy is distorted by a collision with another galaxy. Quasars (quasi-stellar objects) are thought to be galactic nuclei but are so far away that their exact nature is still uncertain. They are compact, highly luminous objects in the outer reaches of the known universe: while the farthest known "ordinary" galaxies are about 12 billion light-years away, the farthest known quasar is about 13 billion light-years away. Active galaxies, such as Seyfert galaxies and radio galaxies, emit intense radiation. In a Seyfert galaxy, this radiation comes from the galactic nucleus; in a radio galaxy, it also comes from huge lobes on either side of the galaxy. The radiation from active galaxies and quasars is thought to be caused by material falling into central black holes (see pp. 28-29).

OPTICAL IMAGE OF NGC 4486 (ELLIPTICAL GALAXY)

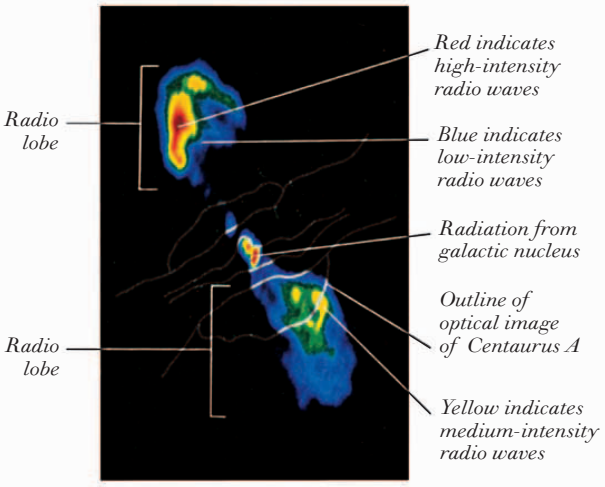
OPTICAL IMAGE OF LARGE MAGELLANIC CLOUD (IRREGULAR GALAXY)

OPTICAL IMAGE OF NGC 2997 (SPIRAL GALAXY)

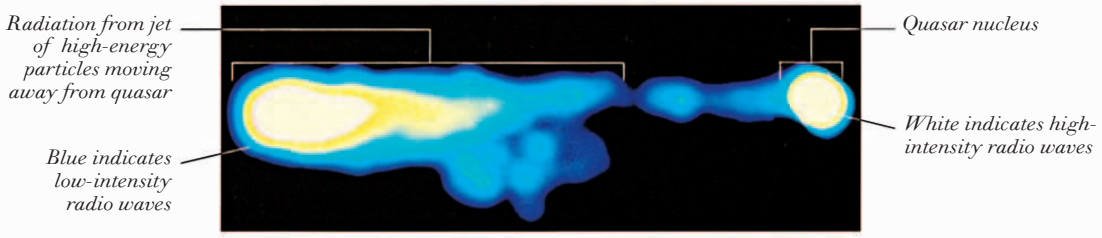
OPTICAL IMAGE OF CENTAURUS A (RADIO GALAXY)



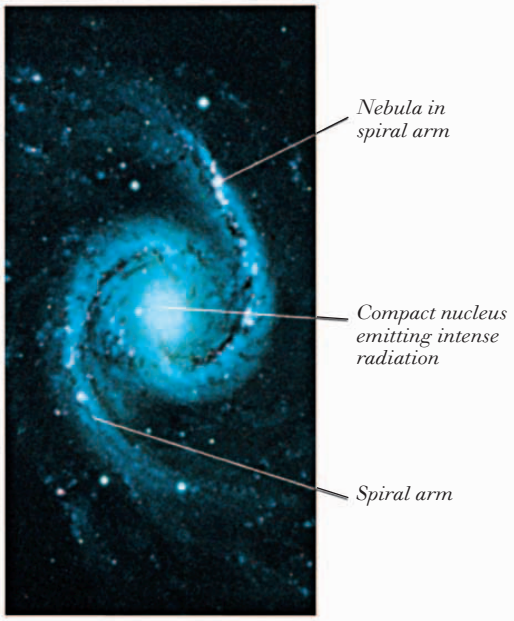
FALSE-COLOR RADIO IMAGE OF CENTAURUS A



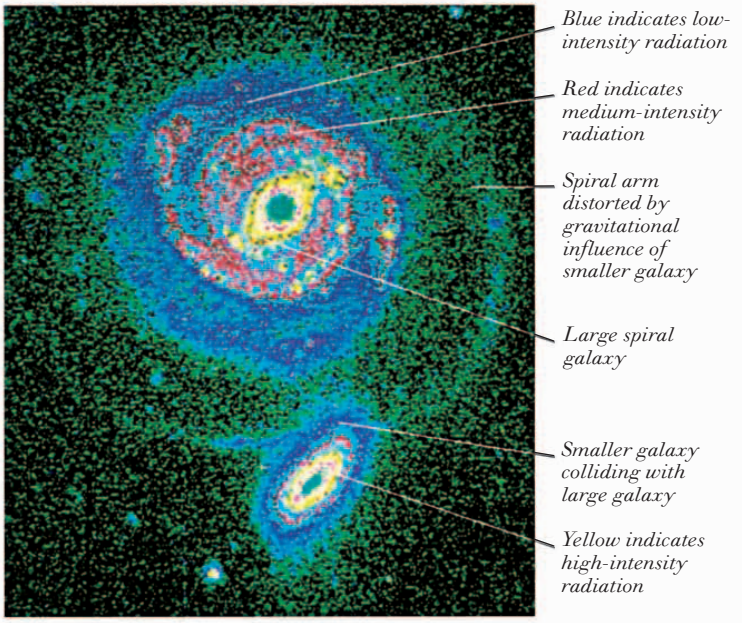
FALSE-COLOR RADIO IMAGE OF 3C 273 (QUASAR)



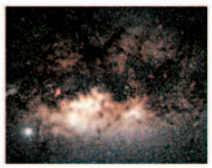
OPTICAL IMAGE OF NGC 1566 (SEYFERT GALAXY)



FALSE-COLOR OPTICAL IMAGE OF NGC 5754 (TWO COLLIDING GALAXIES)



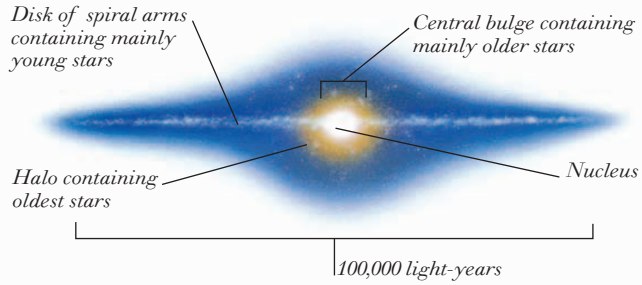
The Milky Way



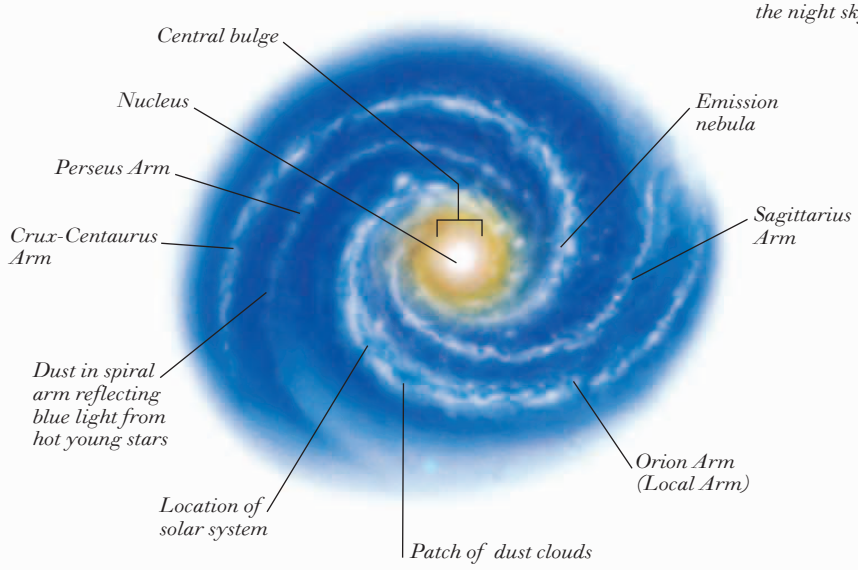
VIEW TOWARD GALACTIC CENTER

THE MILKY WAY IS THE NAME GIVEN TO THE FAINT BAND OF LIGHT that stretches across the night sky. This light comes from stars and nebulae in our galaxy, known as the Milky Way Galaxy or simply as "the Galaxy." The Galaxy is believed to be a barred spiral, with a dense central bar of stars encircled by four arms spiraling outward and surrounded by a less dense halo. We cannot see the spiral shape because the solar system is in one of the spiral arms, the Orion Arm (also called the Local Arm). From our position, the center of the Galaxy is completely obscured by dust clouds; as a result, optical maps give only a limited view of the Galaxy. However, a more complete picture can be obtained by studying radio, infrared, and other radiation. The central part of the Galaxy is relatively small and dense and contains mainly older red and yellow stars. The halo is a less dense region in which the oldest stars are situated; some of these stars are as old as the Galaxy itself (possibly 13 billion years). The spiral arms contain main sequence stars and hot, young, blue stars, as well as nebulae (clouds of dust and gas inside which stars are born). The Galaxy is vast, about 100,000 light-years across (a light-year is about 5,870 billion miles/9,460 billion km); in comparison, the solar system seems small, at about 12 light-hours across (about 8 billion miles/13 billion km). The entire Galaxy is rotating in space, although the inner stars travel faster than those farther out. The Sun, which is about two-thirds out from the center, completes one lap of the Galaxy about every 220 million years.

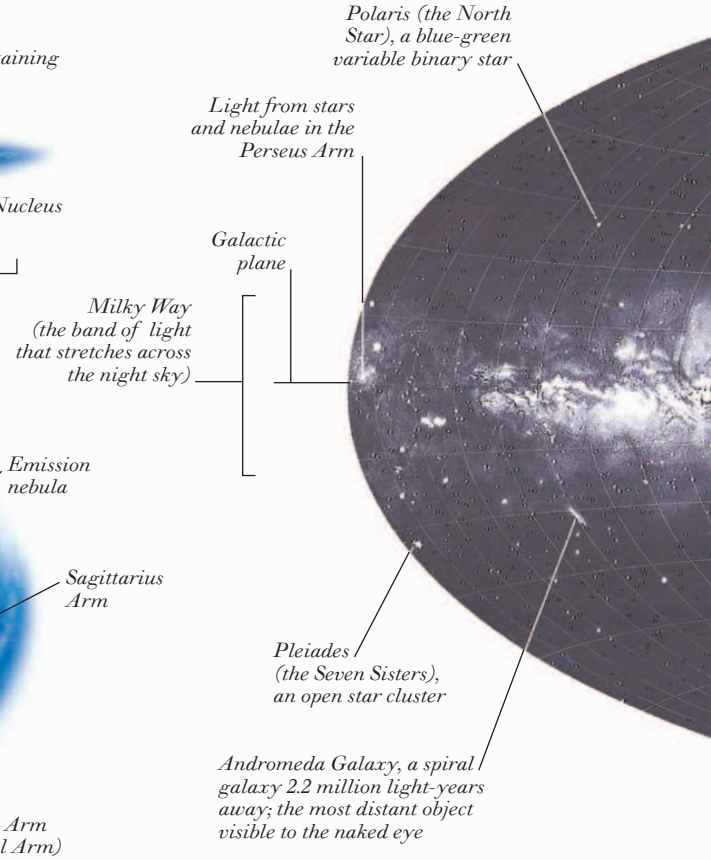
SIDE VIEW OF OUR GALAXY



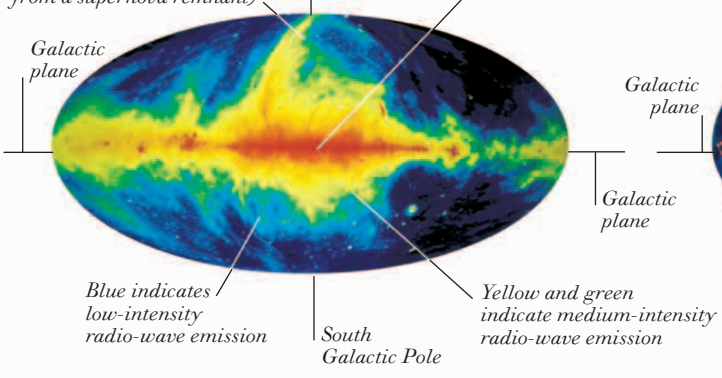
OVERHEAD VIEW OF OUR GALAXY



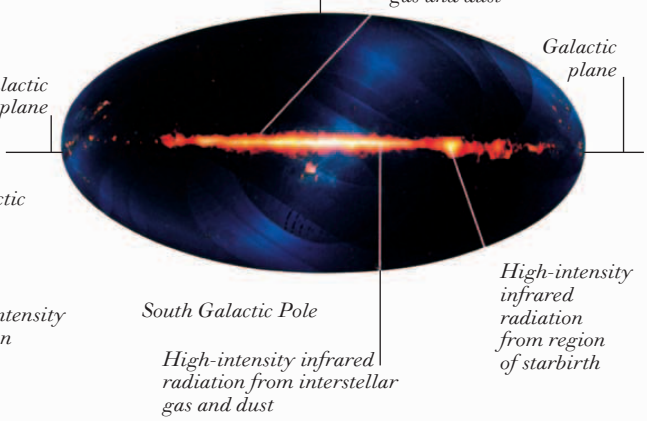
PANORAMIC OPTICAL MAP OF OUR GALAXY AND NEARBY GALAXIES

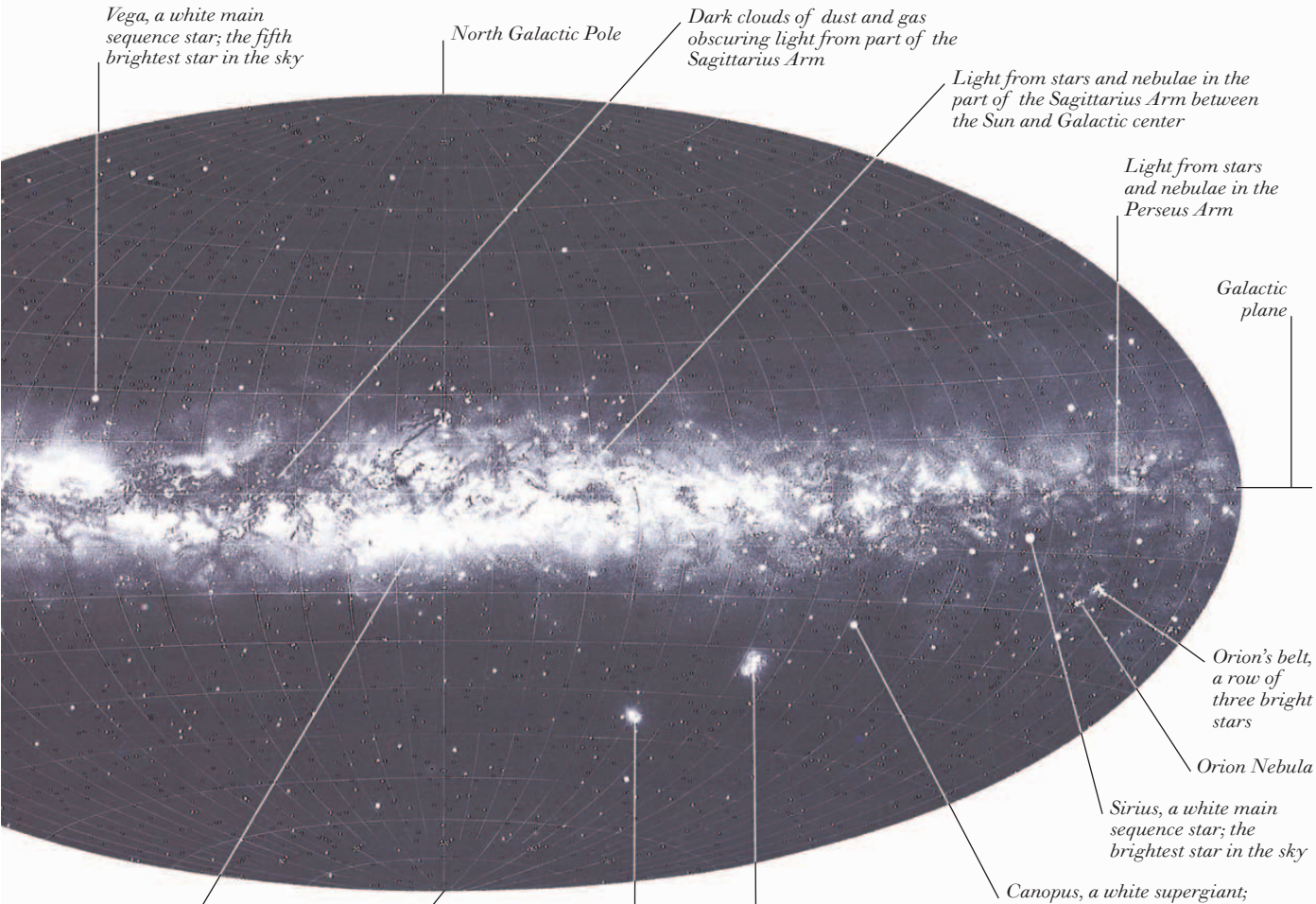


PANORAMIC RADIO MAP OF OUR GALAXY

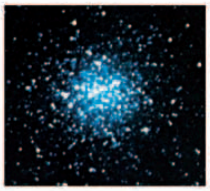


PANORAMIC INFRARED MAP OF OUR GALAXY





Nebulae and star clusters



HODGE 11, A GLOBULAR CLUSTER

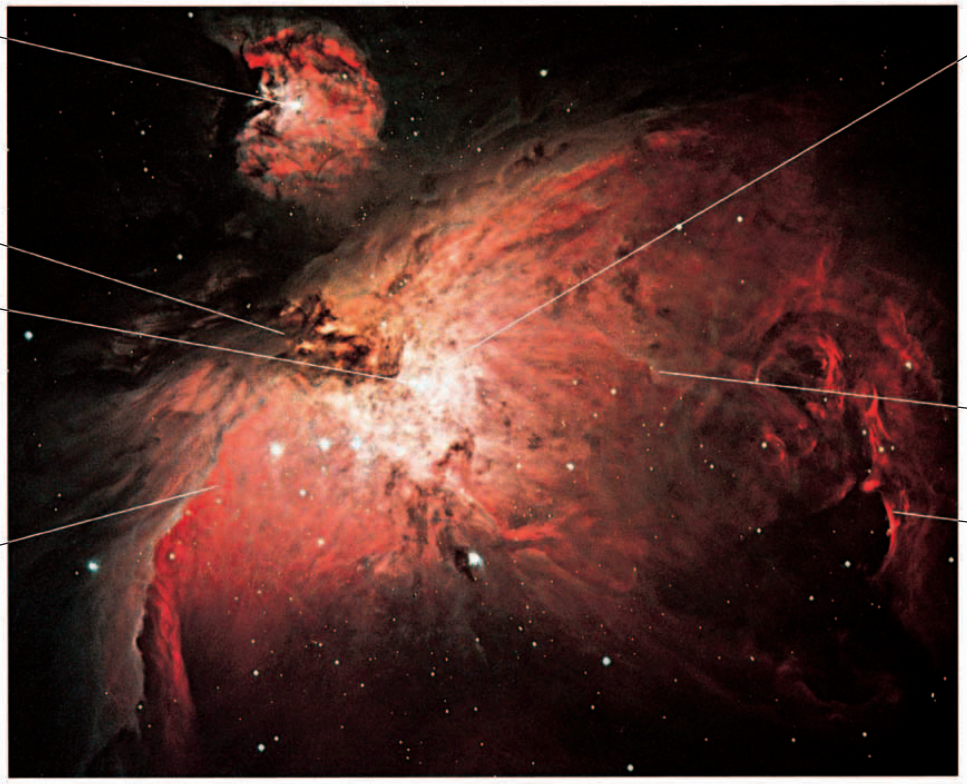
A NEBULA IS A CLOUD OF DUST AND GAS inside a galaxy. Nebulae become visible if the gas glows, or if the cloud reflects starlight or obscures light from more distant objects. Emission nebulae shine because their gas emits light when it is stimulated by radiation from hot young stars. Reflection nebulae shine because their dust reflects light from stars in or around the nebula. Dark nebulae appear as silhouettes because they block out light from shining nebulae or stars behind them. Two types of nebula are associated with dying stars: planetary nebulae and supernova remnants. Both consist of expanding shells of gas that were once the outer layers of a star. A planetary nebula is a gas shell drifting away from a dying stellar core. A supernova remnant is a gas shell moving away from a stellar core at great speed following a violent explosion called a supernova (see pp. 26-27). Stars are often found in groups known as clusters. Open clusters are loose groups of a few thousand young stars that were born from the same cloud and are drifting apart. Globular clusters are densely packed, roughly spherical groups of hundreds of thousands of older stars.

TRIFID NEBULA (EMISSION NEBULA)

PLEIADES (OPEN STAR CLUSTER) WITH A REFLECTION NEBULA

HORSEHEAD NEBULA (DARK NEBULA)

ORION NEBULA (DIFFUSE EMISSION NEBULA)

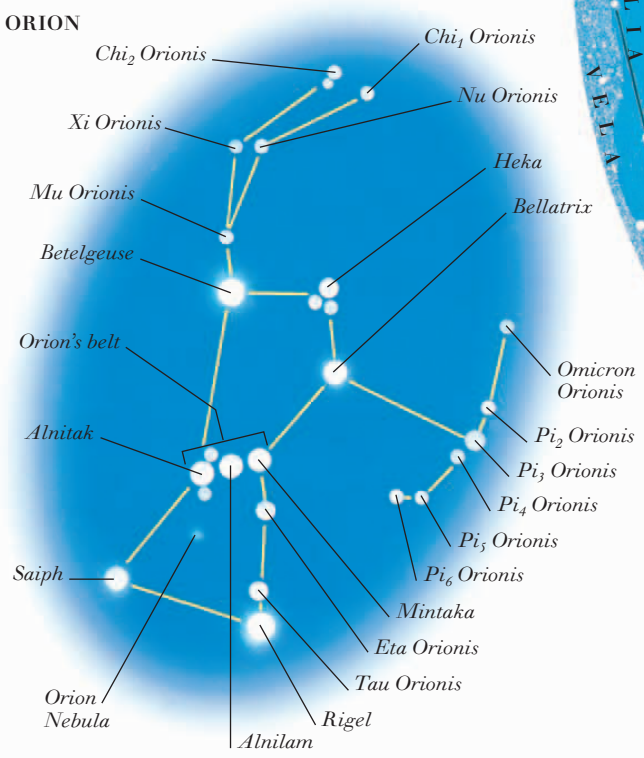


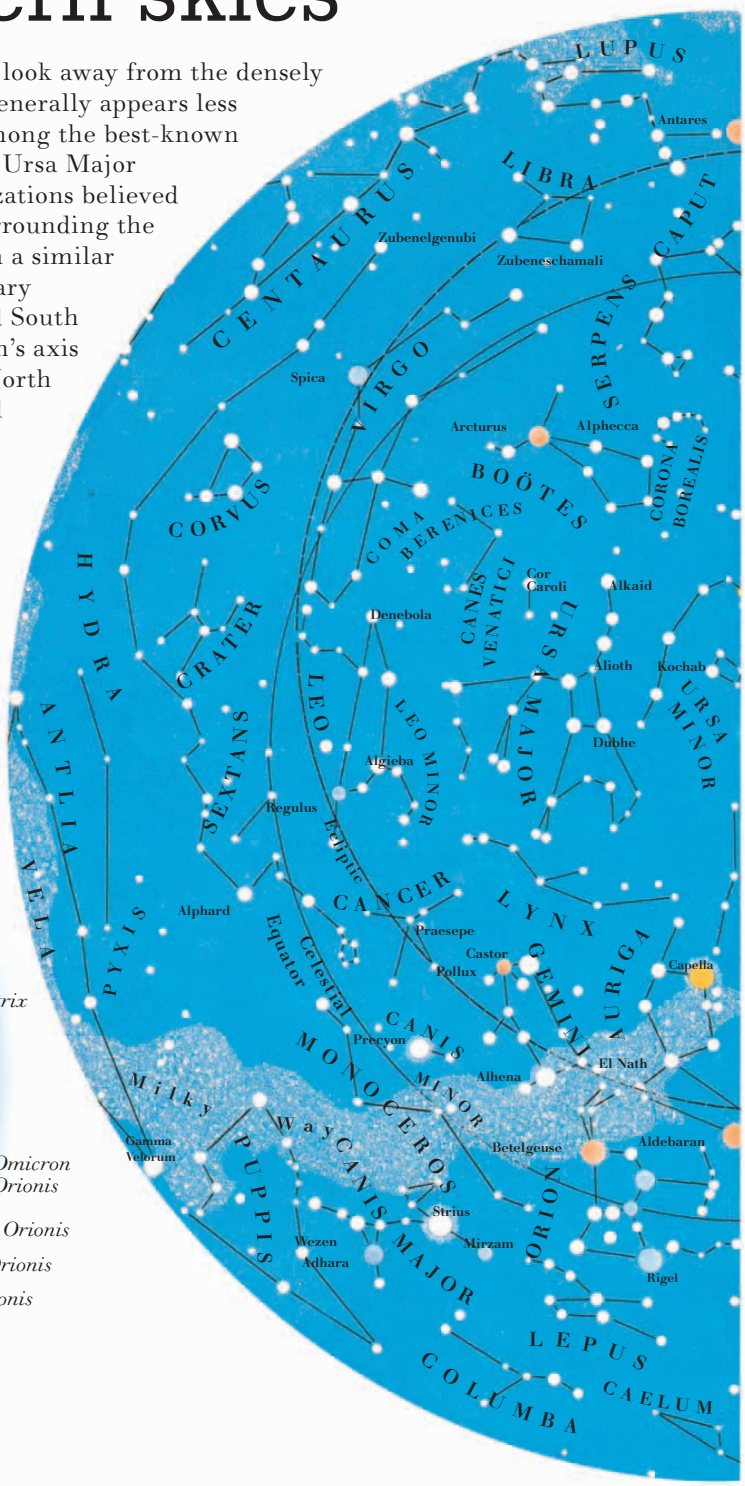
VELA SUPERNOVA REMNANT

HELIX NEBULA (PLANETARY NEBULA)

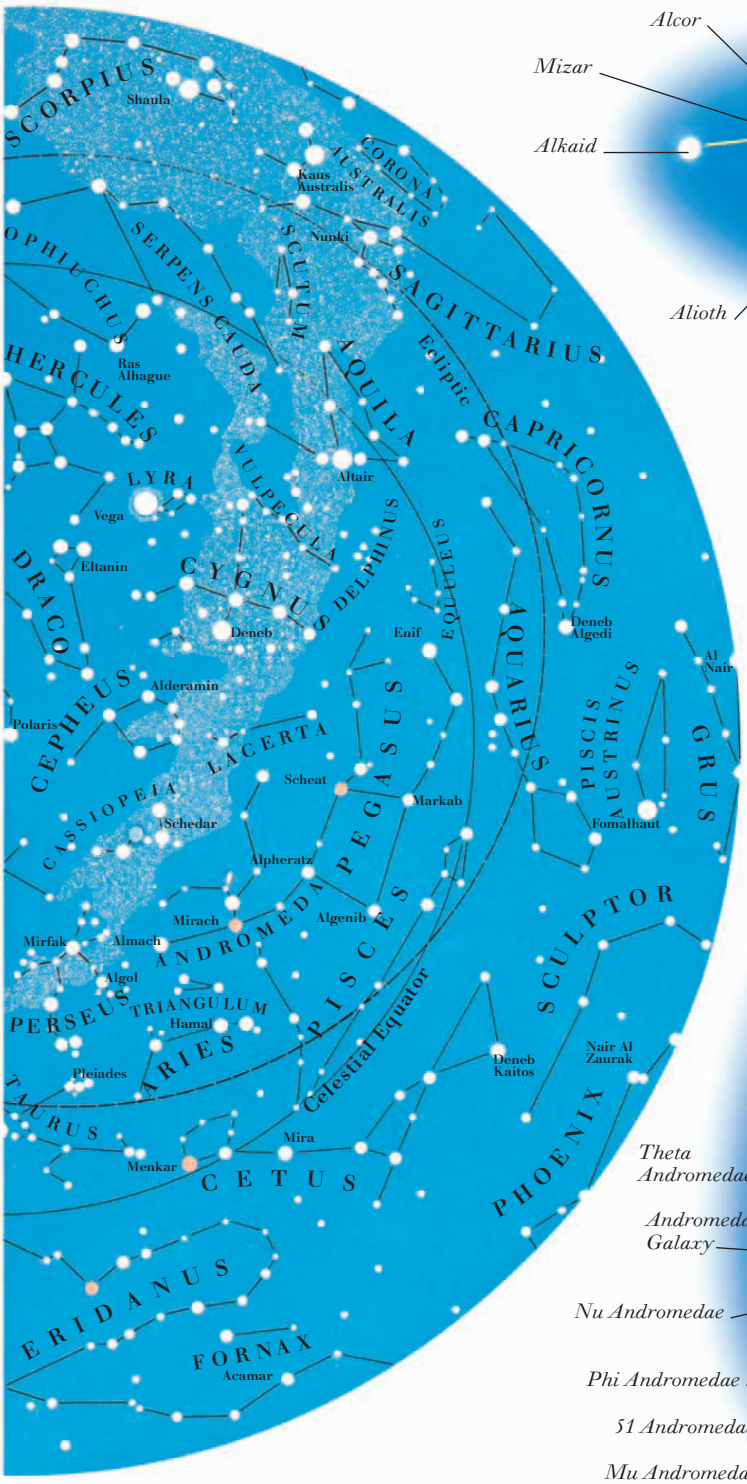
Stars of northern skies

WHEN YOU LOOK AT THE NORTHERN SKY, you look away from the densely populated Galactic center, so the northern sky generally appears less bright than the southern sky (see pp. 20-21). Among the best-known sights in the northern sky are the constellations Ursa Major (the Great Bear) and Orion. Some ancient civilizations believed that the stars were fixed to a celestial sphere surrounding the Earth, and modern maps of the sky are based on a similar idea. The North and South Poles of this imaginary celestial sphere are directly above the North and South Poles of the Earth, at the points where the Earth's axis of rotation intersects the sphere. The celestial North Pole is at the center of the map shown here, and Polaris (the North Star) lies very close to it. The celestial equator marks a projection of the Earth's equator on the sphere. The ecliptic marks the path of the Sun across the sky as the Earth orbits the Sun. The Moon and planets move against the background of the stars because the stars are much more distant; the nearest star outside the solar system (Proxima Centauri) is more than 50,000 times farther away than the planet Jupiter.

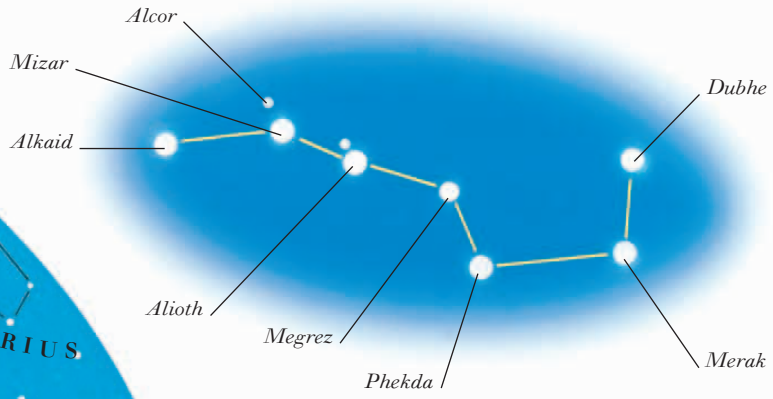




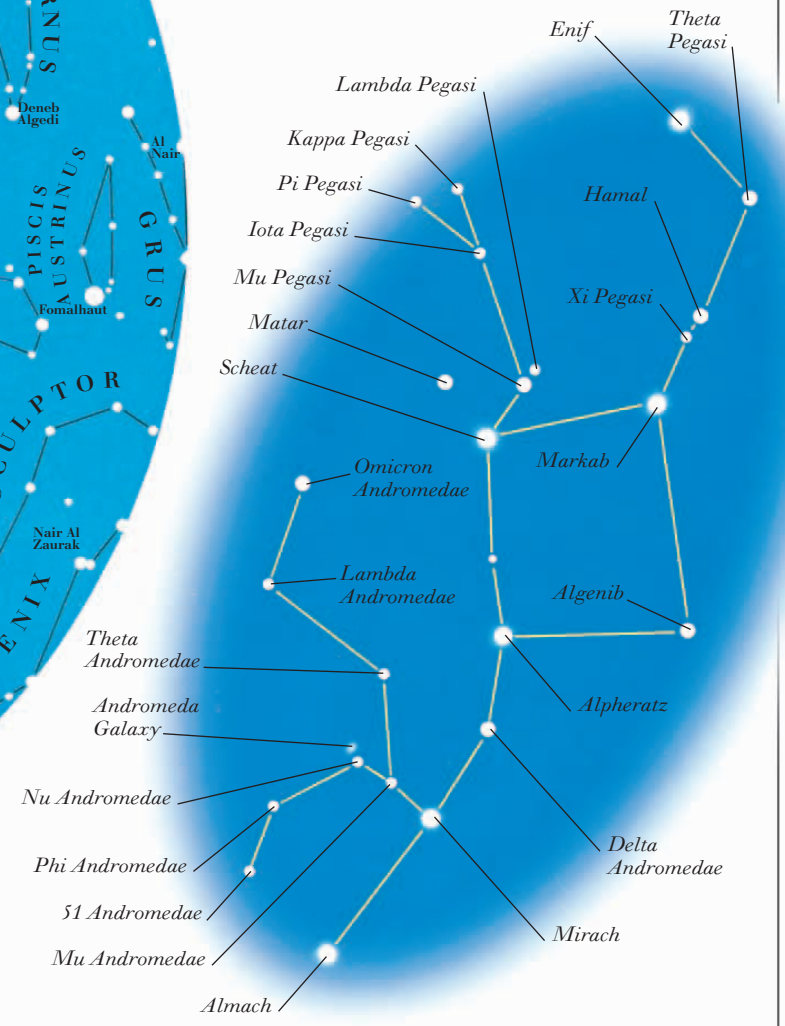
VISIBLE STARS IN THE NORTHERN SKY



THE BIG DIPPER, PART OF URSA MAJOR (THE GREAT BEAR)

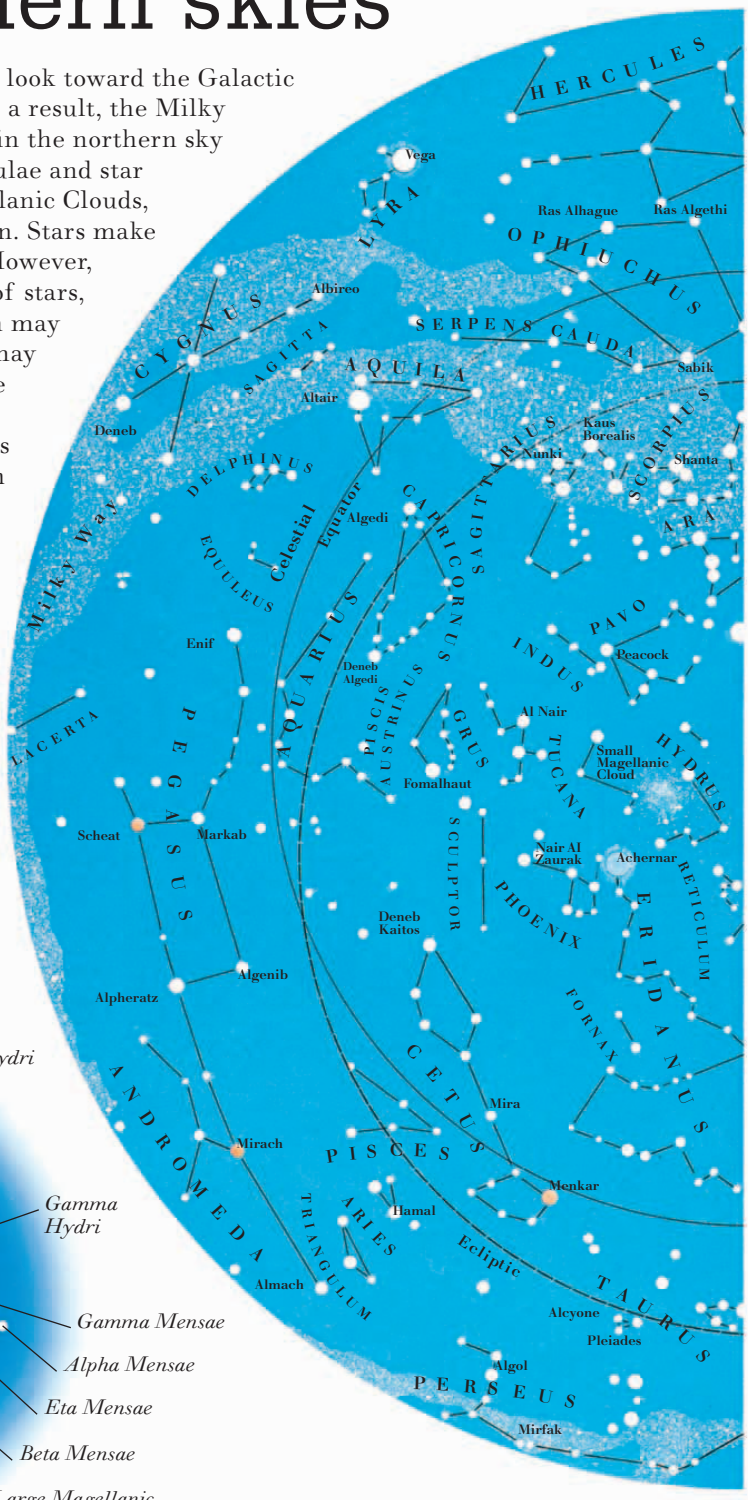


PEGASUS AND ANDROMEDA



Stars of southern skies

WHEN YOU LOOK AT THE SOUTHERN SKY, you look toward the Galactic center, which has a huge population of stars. As a result, the Milky Way appears brighter in the southern sky than in the northern sky (see pp. 18-19). The southern sky is rich in nebulae and star clusters. It contains the Large and Small Magellanic Clouds, which are two of the nearest galaxies to our own. Stars make fixed patterns in the sky called constellations. However, the constellations are only apparent groupings of stars, since the distances to the stars in a constellation may vary enormously. The shapes of constellations may change over many thousands of years due to the relative motions of stars. The movement of the constellations across the sky is due to the Earth's motion in space. The daily rotation of the Earth causes the constellations to move across the sky from east to west, and the orbit of the Earth around the Sun causes different areas of sky to be visible in different seasons. The visibility of areas of sky also depends on the location of the observer. For instance, stars near the celestial equator may be seen from either hemisphere at some time during the year, whereas stars close to the celestial poles (the celestial South Pole is at the center of the map shown here) can never be seen from the opposite hemisphere.



VISIBLE STARS IN THE SOUTHERN SKY

HYDRUS (THE WATER SNAKE) AND MENSA (THE TABLE)