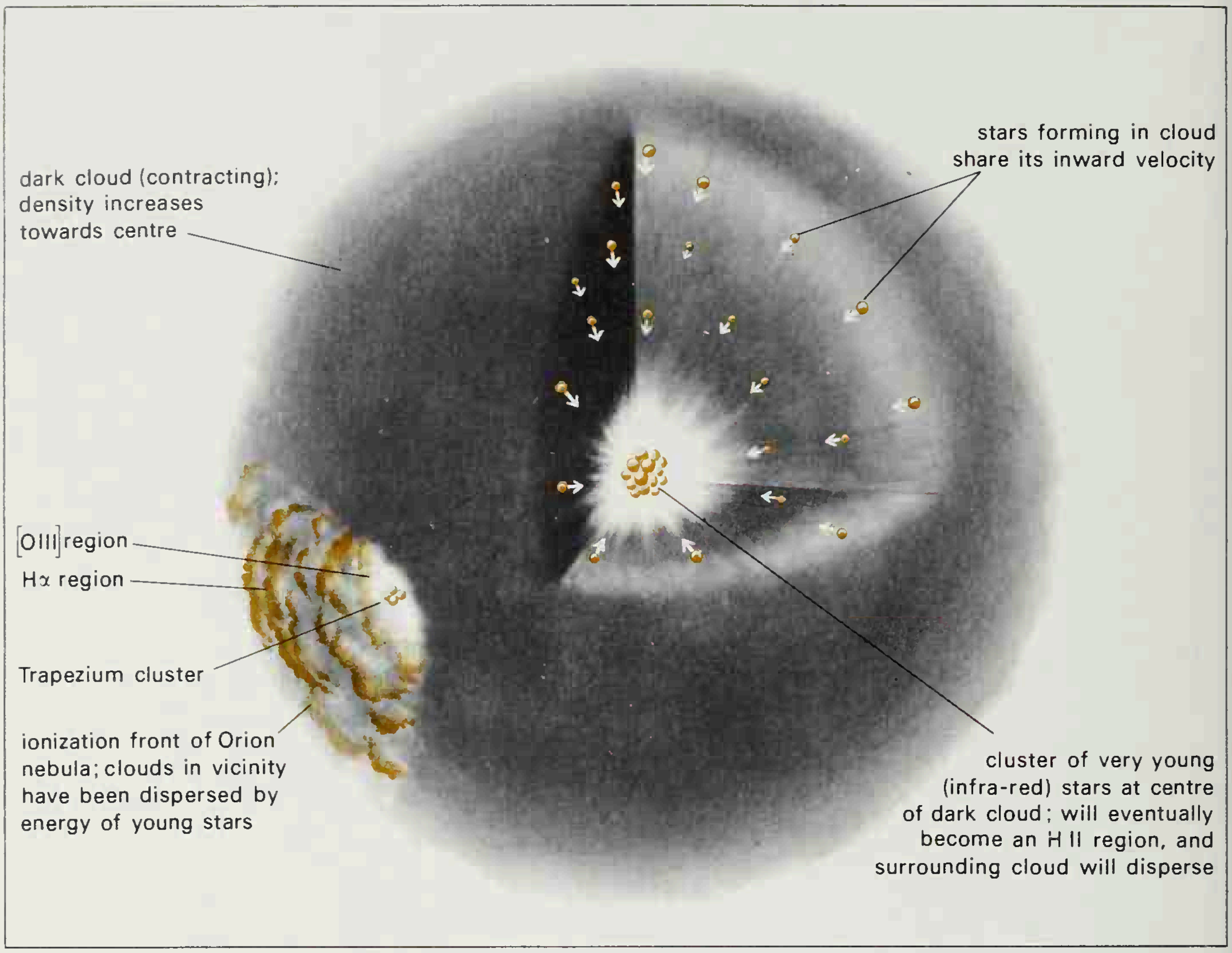

Fig. 6·6
The Orion Nebula is just a small part of a gigantic, non-luminous cloud complex. In this cutaway diagram, we see the Orion Nebula (left) as a region in the cloud where newly-formed stars have excited the gas surrounding them, causing it to glow and expand. The rest of the cloud is collapsing, and many stars are being born in the heavily obscured central regions. Although we cannot yet see these young stars, their radiation will eventually excite the whole cloud complex. (The Sun is situated to the left of the diagram.)

forbidden lines such as these yields much information on the temperatures and pressures in H II regions.

Mixed in with the gas of an H II region are large quantities of obscuring dust particles. Radio waves can penetrate the dust, allowing us to examine the structure of the nebula behind; and, of course, the dust can also be studied for its own sake. Heated by the young stars, the dust grains reach temperatures of up to 300 K, and give out tremendous quantities of energy at infrared wavelengths (from 3–3 000μm). These dust zones in H II regions are among the most powerful infrared sources in the Galaxy, with luminosities up to 10^7 times greater than the Sun.

As we have already noted, there is a strong association between H II regions and the occurrence of star formation. But an H II region does not itself contract and fragment to form stars; in fact, H II regions are observed to be expanding outwards at an average rate of 1 pc every 10^5 years. To find the actual sites of star formation, we must investigate the dark, cool clouds found in association with H II regions: Herschel's 'holes in space'.

Clouds such as these – the Horsehead nebula and the Coalsack are well-known examples – appear to be similar in size and composition to H II regions, but their hydrogen is almost entirely in molecular form (H_2). This is a reflection on the high densities (10^9–10^{10} atoms per m^3) and low temperatures ($T \simeq 10$ K) which prevail: ideal conditions for collapse and fragmentation into stars. Protected from the hurly-burly of ionizing radiations by a cocoon of dust, a cloud may begin to contract undisturbed.

Less common than the dark clouds, but believed by many astronomers to be the sites of active star formation, are the warmer, denser **molecular clouds**. These have densities as high as 10^{10}–10^{12} atoms per m^3 and temperatures between 30–100 K. Many are found in association with giant H II regions and, because they contain large quantities of heated dust, they are strong infrared sources as well. However, their novelty and uniqueness stems from the large and bewildering variety of surprisingly complex molecules which they harbour, most of them unsuspected and unpredicted until their discovery.

Interstellar molecules

A large number of interstellar molecules are now known (Table 6·3), the first few of these being discovered by their absorption lines in the spectra of distant stars. Discoveries by radio methods began in 1963, when the hydroxyl radical (OH) molecule was found at a wavelength of 18 cm. Although molecules also emit energy at ultraviolet and infrared wavelengths, their most intense lines are produced in the millimetre or microwave region of the spectrum, arising out of a change in their rotation rate (ROTATIONAL TRANSITIONS). Many molecules have no net spin unless they collide with another molecule (usually hydrogen, the commonest molecule in space), which sets them into rotation. After a few hours, a spinning molecule will lose all its energy by emitting a photon of microwave radiation, and then return to its GROUND STATE.

It is no coincidence, then, that the sudden rash of