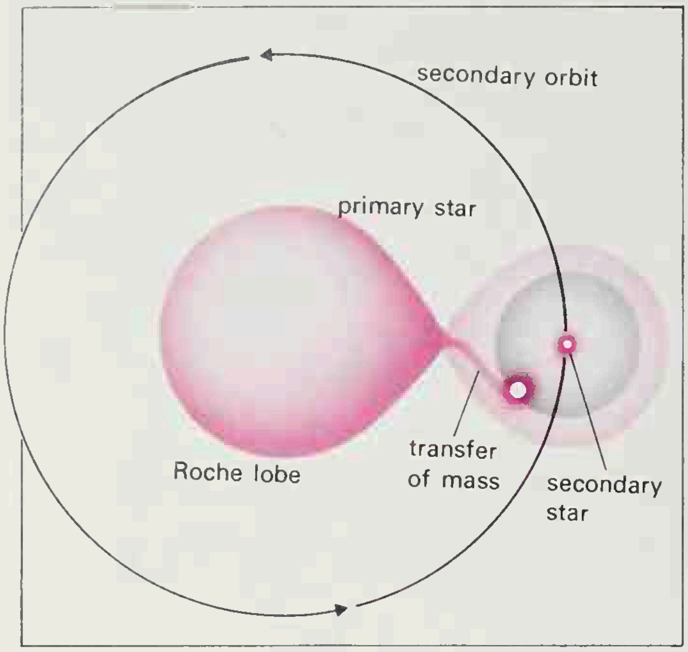

Fig. 3·20 The overall gravitational field in a binary star system has a particular geometrical shape and regions in space may be traced out over which the gravitational field has the same value; these are known as **equipotential surfaces**. *One special case is indicated on the diagram by the tinted area, the two enclosed regions are known as* **Roche lobes**. *An important consideration for close binary stars is that if one fills its Roche lobe, matter may then flow through the lobe onto its companion star, this is then referred to as a semi-detached (β-Lyrae type) binary.*

X-ray variable stars. In these objects, the X-ray variability is found with periods from fractions of a second to days. The former times are typical of pulsation periods of neutron stars, while periods of days represent a binary eclipse period. Some X-ray stars also appear as X-ray novae or flare stars and it is thought that just as in novae, matter pulled gravitationally from one star on to a superdense companion star causes this energetic emission.

As far as regular variables are concerned, it is now widely believed that their variation may be accounted for by pulsations of the stellar surface. Their appearance along what is referred to as the instability strip of the H–R diagram leads astronomers to suspect that these variables are passing through a relatively brief phase of their lives, during which the interior of the star may be in equilibrium but a sub-surface layer exists which is not. It is this layer which produces the oscillations; energy is being stored as the surface contracts and is released when the surface expands. This surface pulsation can be directly observed by measuring the Doppler shift of the spectral lines, demonstrating that the stellar atmosphere really is moving inwards and outwards. This change in surface area of the star is manifest by a change in luminosity which we observe as a regular brightening and fading.

Cepheid variables

The best-known and most-studied group of pulsating stars is the Cepheids, named after the first star of this type observed. This was δ Cephei and its **light curve** (variation of brightness with time) is shown in Fig. 3·21. All Cepheids have light curves similar to this with periods ranging from just over a day to about fifty days. From their position on the H–R diagram, it is apparent that Cepheids are yellow supergiant stars and therefore exceptionally luminous. It is this property which enables them to be detected at large distances and they have been instrumental in determining not only the size and structure of our Galaxy but also the distances of nearby galaxies. This is due to the famous period-luminosity relation for Cepheids, which means that from a measurement of their period the luminosity may be deduced, and, thus, their absolute magnitude. A measurement of the apparent magnitude of the Cepheid then gives its distance (from the distance modulus equation).

The period-luminosity law for Cepheids was discovered in 1908 by Miss Henrietta Leavitt who was studying the Magellanic Clouds. At that time the distance of these clouds was unknown (although we now know they are neighbouring galaxies 50 kpc distant), but they were clearly sufficiently remote for all their stars to be considered to be at the same distance. She noticed that the brighter Cepheids had correspondingly longer periods and because of their equal distance, this showed the existence of a direct link between period and luminosity. However, the distance of at least one Cepheid was required to determine the absolute relation for the group. None are sufficiently close to show trigonometrical parallaxes but studies of star clusters in the early 1960s established the relation reproduced in Fig. 3·22. Because of their high luminosity and tell-tale signature, Cepheids are valuable tools for distance determinations of nearby galaxies and for establishing the basis of observational cosmology.

The understanding of Cepheids in general became much clearer in 1944 when Walter Baade made the discovery of stellar populations (page 166) and found that Cepheids could also be included in this scheme.

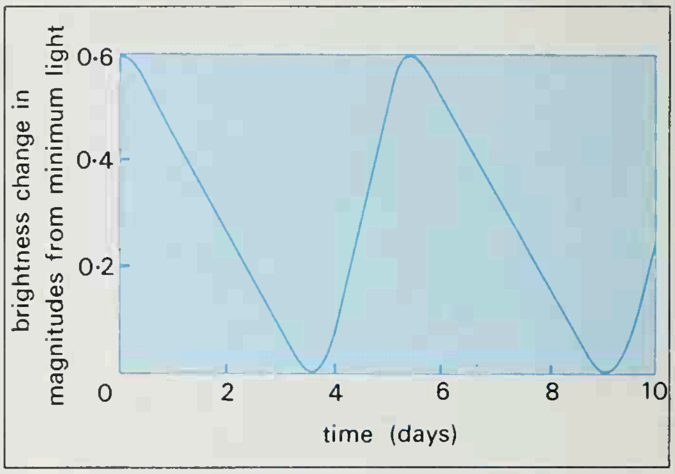

Fig. 3·21 far right, above:
The 5·31 day regular periodic variations in the optical brightness of the star δ Cephei. This was the first star studied in a class of variable, pulsating stars now referred to as Cepheid variables. The pulsation period and the optical period is directly proportional to their luminosity.

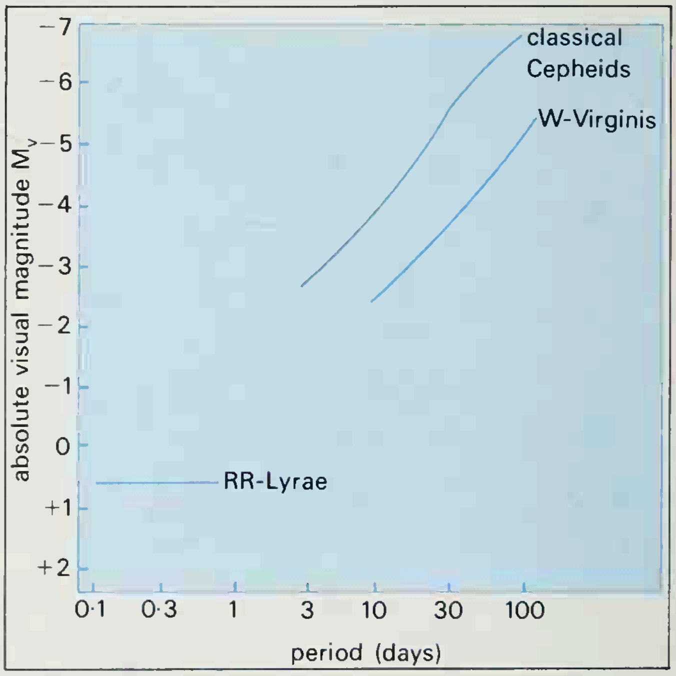

Fig. 3·22 far right, below:
The relationship between the absolute magnitude and optical period for classical Cepheids, W-Virginis and RR-Lyrae variable stars. A measurement of the period for a distant Cepheid enables its absolute magnitude to be derived and a measurement of its apparent magnitude then yields the distance of the Cepheid by application of the distance modulus equation. Cepheids are important tools in the measurement of the distances to galaxies out to a range of about 6 Mpc.