As a typical star, and the only one that can be spatially resolved by direct means, the study of the Sun has provided an insight into many of the fundamental processes taking place in stellar atmospheres, often at small scales. A prime example is magneto-convection or the formation of coronae and the consequent emission of copious amounts of X-rays. In addition, the Sun’s apparent brightness allows measurements with unprecedented accuracy. Thus the Sun is the standard against which cosmic abundances are compared. Its high apparent brightness also means that the Sun is a strong source at almost all wavelengths and thus detectable with simple, not particularly sensitive equipment such as the early instruments flown in space. Thus for many wavelengths the Sun was the first (or one of the first) cosmic source(s) detected.

However, only the lowest layers of the Sun’s atmosphere, the photosphere and chromosphere, can be regularly observed from the ground over the solar disk. The transition region, corona and the solar wind are best studied from space, and even many properties of the photosphere (such as the variation of solar irradiance with time) had to await space-based observations for their determination or discovery.

1 OVERVIEW OF THE SOLAR ATMOSPHERE

Traditionally the atmosphere of the Sun is divided into four layers, starting with the photosphere at the bottom, moving up through the chromosphere and transition region to the corona. The photosphere is the layer in which the temperature drops outwards from around 5800 K at the solar surface to around 4000 K at the temperature minimum. Beyond that point it rises again, first relatively gently (forming the chromospheric plateau), but then very rapidly in the transition region (TR). The temperature profile becomes flatter again in the corona. The boundary between the corona and the TR is often drawn at approximately 10^6 K. This boundary, like that between chromosphere and TR, is not sharp or well defined. At still greater distances from the solar surface the temperature gradually decreases again, achieving values of approximately 10^5 K at 1 AU (whereby electrons and ions need not have the same temperature in the heliosphere). As we shall see in subsequent sections, the simple plane-parallel representation of the solar gas outlined above is not tenable in any layer of the atmosphere. At any given height more than one atmospheric component is present, each having its own temperature, density and velocity structure.

Features as diverse as granular convection cells in the photosphere (Figure 1) and magnetic loops in the corona (Figure 2) are now known to structure the respective layers of the atmosphere. In addition to being spatially inhomogeneous at almost all spatial scales, the solar atmosphere is also highly dynamic at almost all timescales. Much of the interesting physics to be learnt by studying the solar atmosphere is related to this structuring and dynamics and the associated heating of the chromosphere and corona.

In the following we discuss the various atmospheric layers, starting with the photosphere and moving outward. Particular emphasis is placed on the contributions made by space missions to our knowledge and understanding of the solar atmosphere. Since these contributions are largest for the transition region and corona our discussion of these layers will be more detailed than of the photosphere and chromosphere. Table 1 summarizes the space missions mentioned in this chapter.

2 THE PHOTOSPHERE

2.1 The plane-parallel photosphere

The solar photosphere is the layer that emits most of the solar radiative energy flux, with the emitted spectrum...
having its peak in the visible (in the green part of the wavelength range). As such, the photosphere is the atmospheric layer most easily observed from the ground and consequently the one to whose investigation spacecraft have contributed the least. This, however, is changing at a rapid pace, with the ESA–NASA Solar and Heliospheric Observatory (SOHO; Fleck and Domingo 1995) providing the first glimpses of how space-based telescopes can revolutionize our understanding of the photosphere. The next major highlight is expected to be provided by the Japan–US–UK Solar B mission.

The brightness across the solar disk is not constant but rather decreases from the centre of the disk to its edge (the solar limb) at visible wavelengths. This is called limb darkening. Since at the limb the radiation is emitted at greater heights, limb darkening implies a decrease in the temperature with height. Furthermore, the spectral form of the limb darkening provides information on the continuum absorption coefficient. Such observations confirmed the proposal by Wildt (1939) that in the visible the absorption is dominated by the $\text{H}^-$ ion in spite of its low abundance (Chalonge and Kourganoff 1946).

Traditionally the limb darkening and the shapes and strengths of absorption lines (Fraunhofer lines) have been employed to determine the temperature stratification in the solar photosphere. These diagnostics reveal that the temperature decreases outwards in the solar photosphere from over 6500 K at the deepest observable layers to around 4000 K at the temperature minimum (e.g. Holweger 1967). The advent of UV observations from space, in particular