หอสมุดกลาง สถาบันวิทยบริการ จุฬาลงกรณ์มหาวิทยาลัย

Chapter I
Introduction

In this chapter, first we will give a brief introduction about the Sun and its phenomena and next we will overview the purpose of this work. The Sun is a medium-sized star composed of very hot gases, like a large fireball, which is the center of the solar system and very close to the Earth compared with other stars. Not only is it a major natural energy source and very important for the Earth, but the study of the Sun also helps us to understand the other stars. Since the Sun is very close to our Earth, we can observe many phenomena and complex structures of the Sun to find new models and new theories to explain the stars in the universe. Therefore, many astrophysicists try to invent new instruments to observe and record many types of data which help us to understand more about the Sun. The radius of the Sun is about 697,000 km. The schematic diagram of the Sun (Figure 1.1) shows the three directly observable layers of the solar atmosphere:

1. **Photosphere**. Most of the continuum light, or indeed, most of all the radiation emitted by the Sun, is generated from this layer, which can be called the solar surface. Within this region the temperature of the gas decreases from a value of 6500 K at the base of the photosphere to a minimum of 4400 K about 500 km higher. The effective temperature, as determined by fitting a blackbody spectrum to the solar light curve, is about 5770 K.

2. **Chromosphere**. This portion lies above the photosphere and extends

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upward for approximately 2000 km. Then there is a transition region where the temperature increases quickly. The chromosphere is a very thin layer, and it is transparent to most radiation, except for certain spectral (absorption) lines. The temperature of this layer increases from 4400 K to about 25,000 K. The limb chromosphere can be observed for a few minutes before or after a total solar eclipse viewed from the Earth, and has a red color characteristic of a Balmer line of H (the Hα line). Parts of the chromosphere can also be observed daily using special monochromatic filters for the Hα and Ca^{+1} H and K lines.

3. **Corona**. This is the outermost layer, which does not have a well-defined outer boundary. In this layer the temperature increases rapidly to millions of degrees Kelvin, a phenomenon which still cannot be explained. The corona is also very optically thin. Therefore, this layer cannot seen from Earth by the naked eye except during a total solar eclipse. During other times, rough features of the corona can be observed by ground-based instruments called coronagraphs, which block out light from the photospheric disk, but due to scattering in the Earth's atmosphere such photographs are not able to resolve fine structural features. Much better data can be obtained during a solar eclipse, or by the spaceborne coronagraph (LASCO) on board the SOHO mission, which started operation in December, 1995.

In the corona we can observe many types of loop structures, in which loops correspond to magnetic structures of the Sun. Therefore, to explain the magnetic field in the corona, we will study loops which we can observe by means of plasma trapped in the magnetic field. Hood and Priest (1979) observed the solar corona in X-rays and the extreme ultraviolet (EUV) and they identified 5 morphological types of loops:

1. **Interconnecting loops** are the loops which join different active regions (the areas which have a very strong magnetic field) and vary in length

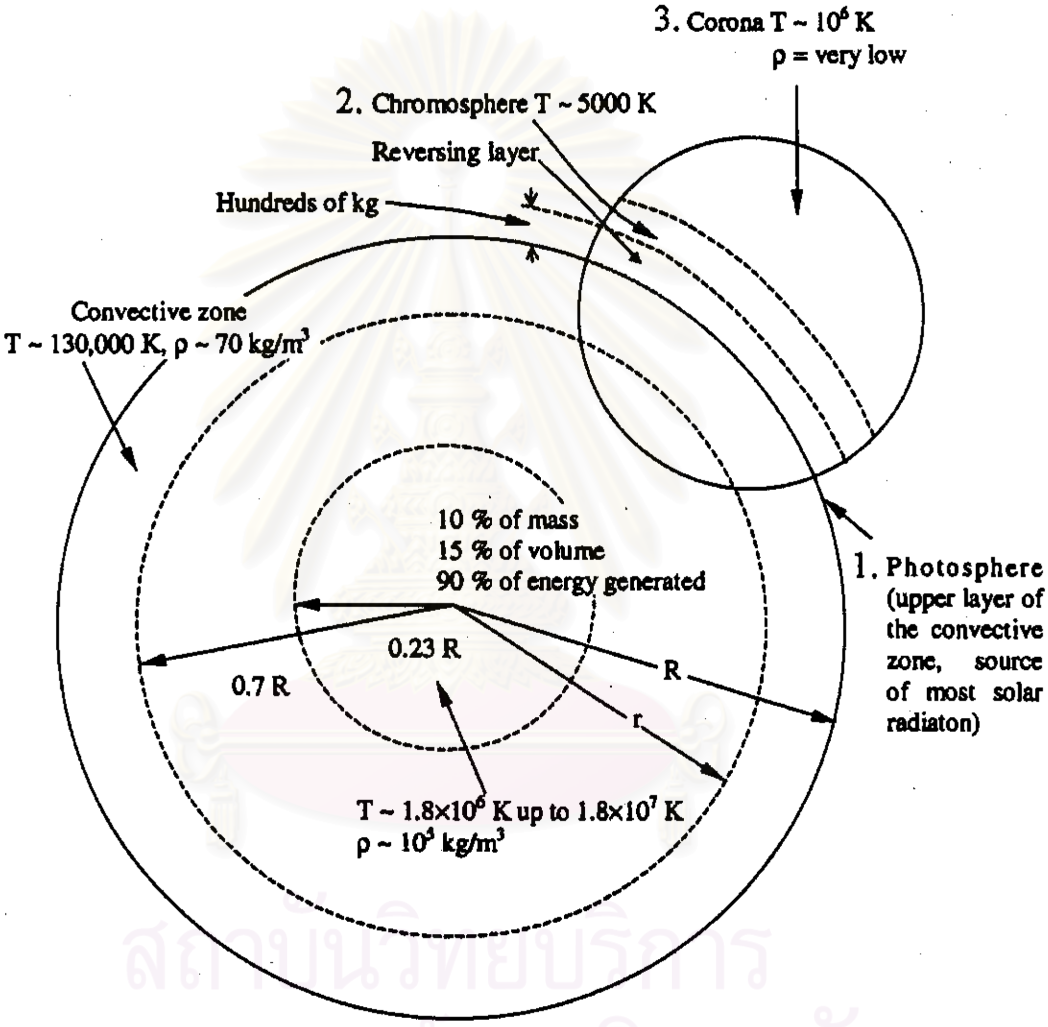

Figure 1.1: The components of the Sun's atmosphere.

from 20 Mm to 700 Mm (1 Mm $\equiv 10^6$ m). Their density is typically 7 $\times 10^{14}$ particles/m^{-3} and their temperature 2 $\times 10^6$ - 3 $\times 10^6$ K.

2. **Quiet region loops** have the same range of lengths but are somewhat cooler (1.5×10^6 - 2.1×10^6 K) and have densities of 2 $\times10^{14}$ - 10 $\times10^{14}$ particles/m^{-3}.

3. **Active region loops** have the length from 10 Mm to 100 Mm and in soft X-rays have a temperature of 2.2×10^6 - 2.8×10^6 K and a density 5×10^{20} - 50×10^{20} particles/m^{-3}.

4. **Flaring loops** which occur in two types:

4.1 **Postflare loops** are 10 Mm to 100 Mm long, with a temperature up to 4×10^6 K and a density of 10^{17} particles/m^{-3}.

4.2 **Simple flare loops** are 5 Mm to 50 Mm long and possess a temperature as high as 4×10^7 K and a density up to 10^{18} particles/m^{-3}.

In Thailand there are a few solar eclipses per century, but the first scientific observation of this event was in the reign of King Rama IV. This and later solar eclipse events were interesting for Thai and foreign people. Four years ago, on October 24th, 1995 there was a total solar eclipse in Thailand. It was viewed by many Thai people, and observations that could potentially be useful scientifically were performed by a research group from Chulalongkorn University, led by Dr. David Ruffolo. This expedition went to observe the total solar eclipse at the Klong Lan National Park in Kampaeng Phet province, located in the northwestern part of Thailand. The observing site of the group was 16° 11′ 59″ N in latitude and 99° 16′ 01″ E in longitude. From this observation we obtained useful data on Fe X (Fe^{+9}) emission, as shown in Figure 1.2, which shows a discontinuous intensity and width in two sets of Fe X loop features. We believe that this has not been observed before, but we need to be sure of the magnetic configuration

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by comparing with magnetic field simulations, which are performed in this thesis work.

In this work, we are interested in the active region loops which are shown in Figure 1.2 and the magnetogram and X-ray images in Chapter III. Previously we introduced the solar atmosphere and the kinds of magnetic loops. Since the loops we are interested in are filled with plasma and magnetic fields, magnetohydrodynamics and magnetohydrostatics are used, as will be explained in Chapter II. In Chapter II, we also explain our generalized model for generating the magnetic field in the force-free case. The initial magnetic field data and data in the form of images are described in Chapter III. The numerical techniques for our simulations are explained in Chapter IV. The results of the simulations and the comparison between the results and the images from observations are shown in Chapter V. Finally, the last chapter gives a discussion and the conclusions.

The Objectives of This Thesis

1. To computationally model the coronal magnetic loop structures on the Sun.

2. To analyze information about the magnetic loops on the west limb of the Sun which were observed during the total solar eclipse on October 24^{th}, 1995.

3. To explain the characteristics of the magnetic loop intensity.

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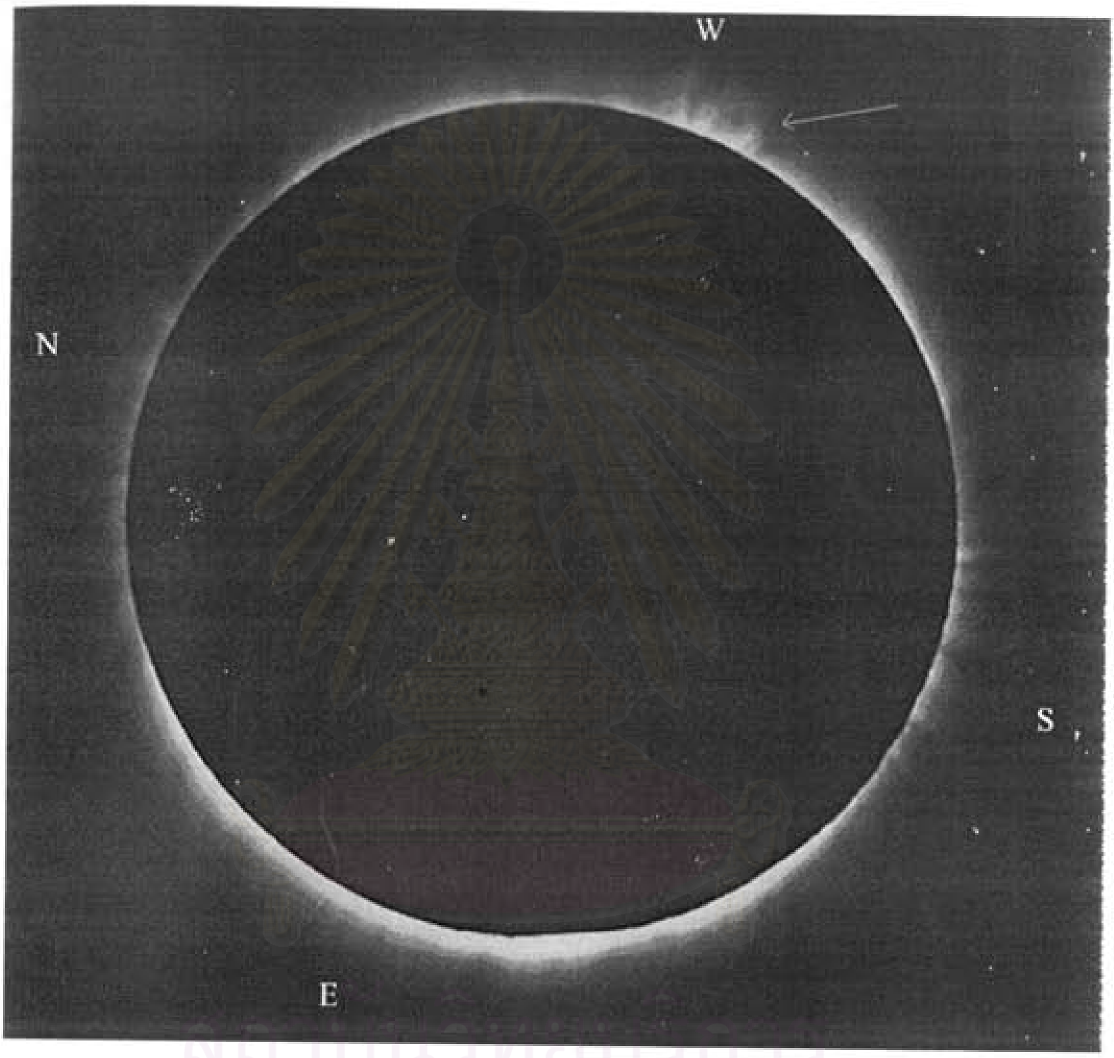

Figure 1.2: The Fe^{+9} image of the total solar eclipse on 24^{th} October, 1995 by a Chulalongkorn University expedition.

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