Chapter 1

Introduction

1.1 WHAT IS A BE STAR?

Be stars are main-sequence stars that show or have shown emission lines in their Balmer series. This emission is principally due to radiative recombination in a disc-like envelope or ionised circumstellar gas. These stars form a large subgroup, about 20%, of the B type stars with maximum frequency at type B2–B3. Thus, their existence cannot be ignored in theoretical studies. In addition, the presence of emission lines is pervasive throughout the HR diagram. One can find emission line stars of every spectral type in the HR diagram. Among the emission line stars, the Be stars have been the ones observed most frequently.

In accretion systems such as protostellar nebulae, or in a close binary system with mass transfer, discs form to provide the outward viscous transport of the angular momentum of the infalling material (Frank, King & Raine, 2002). Be stars are too old to have retained a protostellar disc. Mostly, the Balmer emission lines, which originate from the disc are observed as present and absent on timescales of months or decades. In addition, the mass transfer of close binary systems is generally not found in Be stars. Thus, the stars lack a source of material from the outside with which to form a disc. This means that the materials of the disc originate from the ejection or decretion of mass from the underlying star at the centre. The mechanisms by which material from the underlying stars is caused to be ejected into orbit and held in stable orbit are still under debate. One of the factors that can drive material into orbit is rapid rotation. However, rapid rotation alone is not sufficient for the appearance of the Be phenomenon in B stars (Limber & Malborough, 1968). Some of the models created can usually only explain the Be phenomenon in the program stars under study and none of the models can represent the mechanism for all Be stars. This could mean that all Be stars are unique.

In the aspect of evolutionary status of Be stars, the understanding of the appearance of the Be phenomenon in the B star's main sequence lifetime also changes with time. Amongst the earliest ideas was that proposed by Schmidt-Kaler (1964), who suggested that the Be phenomenon occurred during the core contraction phase following the exhaustion of hydrogen. Then, it changed to appear close to the zero age main sequence star (ZAMS) when a significant fraction of Be stars was found in the stage of hydrogen burning, i.e., in the early evolution of the main sequence (Schild & Rominishin, 1976). Mermilliod (1982) and Slettebak (1985) then produced a result that suggested that the Be phenomenon could occupy or appear in any region of the main sequence band and in different evolutionary states. However, later studies of Be abundance in open clusters found that Be stars appeared in all ages with a peak frequency turn-off at spectral types B1–B2 in the main sequence band and a subsequent regular decrease with increasing age (Mermilliod, 1982; Grebel, 1997; Fabregat & Torrejon, 2000). This led to the suggestion that the Be phenomenon is related to a star's evolutionary age and that the occurrence of the Be phenomenon is during the second half of the main sequence lifetime of a B star (Fabregat & Torrejon, 2000), because the phenomenon can be related to the main structural changes happening at this evolutionary phase.

1.2 GOALS OF THIS WORK

This dissertation presents an analysis of the Be disc characteristics of δ-Scorpii (hereafter δ-Sco) in the optical range for the years from 2007 to 2011 via its spectral data. δ-Sco is a binary star with a highly eccentric orbit and a period of ~10.6 years. Although its orbital period is more than 10 years, the high eccentricity leads to a non-negligible tidal interaction during the periastron. In previous work, this star was first shown to have a weak H_{α}emission line in 1990 and the emission line was found stronger during the next periastron in 2000, in which an enhanced mass loss phase has been detected (Miroshnichenko et al., 2001).

In this work, we monitored and studied the optical spectral characteristics or behaviours of the lines in a Be disc of the star. The recent periastron that occurred in July 2011, when the stars become closest, has been investigated via its spectral variation to determine whether this event could potentially be one of the causes for this star to become a Be star, or at least a reason for the survival of the Be disc. In this work, we also attempt to fit one of the Be disc characteristics, the V/R variation, into the one-armed oscillation disc model (Okazaki, 1991).

In the final part of this work, we carried out an evolutionary study by generating a few models of evolutionary tracks using the EV stellar evolution code (Eggleton, 2002) with certain initial parameters. The intention was to identify the current status of the star on the model tracks based on the effective temperature, which was adopted in this study, or on its estimated radius, mass or other physical parameters, which have been studied by other people. The evolution of other parameters, namely the rotational velocity and rotation rate were also studied. The correlation between the appearance of the Be phenomenon in this star and the evolution process in the model tracks also became one of the interests in this work.

1.3 MOTIVATION OF THIS STUDY

In this study, the spectral variations of δ-Sco in the optical region have been investigated thoroughly using several hundreds of spectra of this star from the BeSS database for the years 2007 to 2011 when the star happened to encounter the periastron passage in July 2011. The periastron passage in July 2011 was actually the third close encounter since the star was recognised as a Be star; the second encounter occurred in September 2000. We hope to find a possible correlation or at least a clue for the Be phenomenon of this type of star.

The remainder of this dissertation is organised as follows. The background knowledge of Be stars is explained in chapter 2. Our program of Be star is explained in Chapter 3. Chapter 4 describes the techniques and procedures used in measuring the data for the analysis. All the analysis work with some discussion is explained in Chapter 5. The evolutionary study of this star is explained in Chapter 6 and finally, the discussion and conclusions are presented in Chapter 7.