About 400 million years after the big bang, the dark age of the universe ended when the first stars formed and re-ionised the universe. Most of the stars formed at that time died a long time ago but it is possible to study their properties by looking at the chemical imprint they left on low mass stars that have a lifetime longer than the age of the universe (about 13.4 billion years). Such low mass stars can be found in the halo of our galaxy and are called extremely metal poor (EMP) since some of them have 100,000 times less iron than our Sun. This project is aimed at (1) the understanding of the characteristics of the first stars in the universe using stellar models and the database of observed metal-poor stars, and (2) the exploration of the mixing in one and three-dimension stellar models to improve our understanding of stellar evolution and nucleosynthesis. We have accomplished a high achievement in both parts of the project and enlarged our opportunity of future collaborations as described below.

(1) The applicant researcher (Dr. Suda) set up the web site of the database of metal-poor stars at the host institute (The SAGA database, http://www.astro.keele.ac.uk/saga/). This site is the mirror site of the database developed in Japan. The mirror site enables Dr. Suda and collaborators to access the database locally and to promote the statistical argument on the star formation history of our Galaxy. Along with the further update of the database, Dr. Suda summarized the general properties of the observed metal-poor stars in the Galactic halo in terms of element mixing in low- and intermediate-mass stars, Galactic chemical evolution, and nucleosynthesis in stars (Suda et al., submitted to MNRAS). In this paper, he finds important link between observed carbon-enhanced metal-poor stars and the models of low- and intermediate-mass stars through the mechanism of element mixing during the late stages of stellar evolution at low metallicity. He also discusses the chemical enrichment of our Galaxy using the relation between element abundances, which can constrain the nucleosynthesis in supernovae and initial mass function at the early epoch of the Galactic halo formation. The Keele group have started the research on the chemical imprints of the first stars and on the chemical history of our Galaxy based on observed data of metal-poor stars and on the evolution of massive stars. The Keele group, in collaboration with Geneva Group in Switzerland, thoroughly discussed the origins of elements in the very early Galaxy using the models of massive stars and the database (Meynet, Hirschi, et al., accepted by A&A). These two works cover the possible scenarios for the star formation history of our Galaxy considering the role of stars in the entire mass range.

(2) Dr. Suda and Keele group of Dr. Hirschi (http://www.astro.keele.ac.uk/~hirschi/) have started the code comparison of 1D stellar evolution code to understand the connection between 1D and 3D scheme for nucleosynthesis and mixing in stars. Dr. Suda has obtained the details of the evolution of low- and intermediate-mass stars at low metallicity with 1D stellar evolution code (Suda & Fujimoto 2010, MNRAS). In this work, he discovered various channels to change the surface chemical composition of stars in the early universe. In course of the collaboration, Dr. Suda and Dr. Hirschi in Keele group identified a promising research topic on stellar models which is essential in understanding the impact of changing input physics on the

stellar models. As an exploration of this research area, they started the collaboration work on nuclear reaction rate that enables us to promote the knowledge of the code comparison (Suda, Hirschi, and Fujimoto, AIP Conference series, in press, to be submitted to MNRAS). They also started using the new 1D stellar evolution code (mesa code, which is useful for the code comparison) that is developed by the Keele group in collaboration with Canadian and American institutes. Finally, the Keele group and Dr Suda have already developed a variety of computer programs to investigate the link between diffusion in 3D and 1D models. 1D/3D connection of stellar models is to be further explored beyond the term of the fellowship as a future collaboration.

This project produced 11 journal papers in total. In five of them, Dr. Suda contributed as a leading author. Dr. Suda also actively participated in conferences and seminars. He attended 6 conferences and delivered 6 seminars during this fellowship.

With regards to the research training activities, Dr. Suda took English language classes to improve his language skill. Keele has various classes of English language for students from non-English speaking countries. He took three classes per week for the first three months. He also found a student who is interested in language exchange. Dr. Suda had an experience of learning English and also teaching Japanese once a week for 9 months.

Transfer of knowledge activities was successful. Dr. Suda gave a seminar to the astrophysics group in Keele where he presented his research activities. In addition, he and Keele group have opportunities of discussions about research progress and newly published papers during the daily informal meeting at lunch time.

The project will have a strong impact on and many uses in the field of astronomy since we studied the origin of the composition of EMP stars considering stars with initial masses covering the full initial mass function and this has allowed us to explain most trends observed in these stars. The database in place now at Keele has allowed us to more efficiently compare models and observations and this technological advantage will continue to benefit us and other research groups. The database will also continue to allow a better statistical description of EMP stars as has been done by Dr. Suda during this project.

The development of computer programs in 1D and 3D and also program linking diffusion in different dimensions will continue in the future and will certainly lead to better models of the structure and evolution of stars. This will provide valuable theoretical predictions to be compared to current and future surveys of EMP stars like the SEGUE survey, which will be included in the SAGA database in order to maximise the pace of scientific knowledge development.