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Chinese Astronomy and Astrophysics 39 (2015) 454–465

CHINESE
ASTRONOMY
AND ASTROPHYSICS

Parameter Estimation of Stellar Population Synthesis Using A Combined Genetic Algorithm[†] [⋆]

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Abstract For the galaxies composed of different kinds of stars, it is important to estimate the parameters of stellar population synthesis quickly and accurately from the massive data of galactic spectra. It is presented in this paper that the combination of the genetic algorithm (GA) with the simulated annealing (SA) algorithm has the complementary advantages of the good global search ability and fast convergence of GA, as well as the strong local search ability of the SA algorithm. In both the speed and accuracy of the parameter estimation of stellar population synthesis, the GA-SA combined algorithm is superior to the single SA algorithm.

Key words galaxies: fundamental parameters—galaxies: stellar population—techniques: spectroscopic—methods: data analysis

1. INTRODUCTION

The observed spectra of galaxies contain rich information about the galactic formation, motion, structure, and evolution, which are fundamental for revealing the origin, evolution, large-scale structure, and other physical properties of the universe. For the galaxies composed of different kinds of stars, the stellar population synthesis is one of effective methods to analyze the galactic spectra. Using the evolutionary tracks and spectroscopic database of stars, the stellar population synthesis method makes fitting on the observed galactic spectra, and by through the estimation and comparison of fitting parameters, to analyze the stellar population composition of galactic spectra, so that not only to obtain the properties of

[†] Supported by National Natural Science Foundation (11203006, 11303003) and Natural Science Foundation of Shangdong Province (ZR2012AM008)

Received 2014–05–09; revised version 2014–10–08

[⋆] A translation of *Acta Astron. Sin.* Vol. 56, No. 2, pp. 93–100, 2015

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doi:10.1016/j.chinastron.2015.10.003

galaxies, such as their age, metal abundance, star formation history, mass-luminosity ratio, etc., but also to serve as a supplementary measure for studying other astronomical problems (such as the active galactic nuclei)[1−5].

Now, accompanying with the implementation of more and more spectroscopic sky survey projects, such as the SDSS[6−7] (Sloan Digital Sky Survey), LAMOST[8−10] (Large Sky Area Multi-Object Fiber Spectroscopic Telescope), and so on, the resources of observed galactic spectra become increasingly rich. For the massive data of galactic spectra, adopting an automatic algorithm to estimate rapidly and accurately the stellar population synthesis parameters is key important for displaying fully the effectiveness of the stellar population synthesis method. The essence of the parameter estimation of stellar population synthesis is the search in the parametric space, which makes the χ^2-value between the modeling spectrum and the observed spectrum minimal. The existing methods[11−13] adopt the Metropolis simulated annealing (SA) and Markov chain[14]. Although Reference [15] has proved that beginning from an arbitrary initial point, if a sufficiently long Markov chain is produced according to certain conditions, then the SA algorithm will converge to the global minimum with the possibility of 1.0. But in practice, because that the length of Markov chain and the time of computation are limited, hence, the algorithm generally exhibits a stronger local search ability, but a weaker global search ability, and the finally converged result depends rather large on the initial value.

On the other hand, the genetic algorithm[16−19] (GA) simulates the genetic and evolutionary processes of living beings in the nature, and makes parallel searches starting from multiple points in the parametric space, it can rapidly converge to the 90% of globally optimal solution by selection, crossing, and mutation, and it is favorable to the parallel realization of hardware, but later it will converge slowly, and needs a number of iterations and more time to attain the really optimal solution. Therefore, the genetic algorithm belongs to an algorithm with a strong global search ability, but a weak local search ability.

This paper applies the combination of the genetic algorithm and simulated annealing algorithm to the parameter estimation of stellar population synthesis. The two algorithms are complementary each other, on the basis of the SA algorithm, the advantages of strong global search ability and rapid convergence of GA are sufficiently used. The experimental results indicate that for the speed and accuracy of the parameter estimation of stellar population synthesis, the GA-SA combined algorithm is superior to the single SA algorithm. This paper is organized as follows: first of all, the stellar population synthesis method and the parameter estimation of stellar population synthesis based on the SA algorithm are described, then the GA and the principle and procedure of the GA-SA combined algorithm are described, and finally, the experiments and discussion are given.