Chapter 4.11
Cooperative AI Techniques for Stellar Spectra Classification:
A Hybrid Strategy

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ABSTRACT

This chapter describes a hybrid approach to the unattended classification of low-resolution optical spectra of stars. The classification of stars in the standard MK system constitutes an important problem in the astrophysics area, since it helps to carry out proper stellar evolution studies. Manual methods, based on the visual study of stellar spectra, have been frequently and successfully used by researchers for many years, but they are no longer viable because of the spectacular advances of the objects collection technologies, which gather a huge amount of spectral data in a relatively short time. Therefore, we propose a cooperative system that is capable of classifying stars automatically and efficiently, by applying to each spectrum the most appropriate method or combined methods, which guarantees a reliable, consistent, and adapted classification. Our

final objective is the integration of several artificial intelligence techniques in a unique hybrid system.

INTRODUCTION

This chapter is part of a global project devoted to the study of the last phases of stellar evolution. Evolutionary studies are an essential part of astrophysics because they allow us to discover and follow the temporal changes of the physical and chemical conditions of the stars. The general objective of our project is the development of an automatic system for the determination of the physical and chemical stellar parameters (spectral type, luminosity, temperature, metallicity, etc.) through optical spectroscopy and artificial intelligence techniques.

Spectroscopy is among the most powerful, currently available techniques for the study of stars and, in particular, their physical conditions (temperature, pressure, density, etc.) and chemical components (H, He, Ca, K, etc.). In general terms, a stellar spectrum consists of a black body continuum light distribution, distorted by the interstellar absorption and reemission of light, and by the presence of absorption lines, emission lines, and molecular bands (Zombeck, 1990).

The stellar spectra are collected from telescopes with appropriate spectrographs and detectors. Observers collect the flux distribution of each object and reduce these data to obtain a one-dimensional spectrum calibrated in energy flux ($erg^{-1}cms^{-2}s^{-1}Å^{-1}$) and wavelength (Å).

As part of the global project, we have collected a large sample of optical stellar spectra from astronomical observations carried out at several telescopes. Once the spectra of a homogeneous sample of stars are collected and reduced, the study of the distribution of spectral types and the analysis of spectral data can help to understand the temporary change of the physical conditions of stars from a statistical point of view, and therefore, to learn about their evolution. This is why spectral classification is one of the fundamental aspects of the evolutionary study of stars, and a phase that must be carried out in a fast, efficient, and accurate way.

In order to extract useful information from the individual spectra and to study the stellar evolution in the whole sample, we must complete a solid and systematic spectral classification of our collected spectra in the current Morgan-Keenan system (MK).

The MK classification system was firstly proposed in 1943 by Morgan, Keenan, and Kellman and has experienced many revisions ever since (Morgan, 1943). This two-dimensional system is the only one that is widely used for stellar classification. One of its main advantages is that MK classifications are often static because they are based on the visual study of the spectra and on a set of standard criteria. However, the same spectra can be classified differently by different experts and even differently by the same person at different times. This classification system quantifies stellar temperatures and levels of luminosity. Stars are divided into groups (i.e., spectral types) that are mainly based on the strength of the hydrogen absorption lines and on the presence or absence of some significant lines of Ca, He, Fe, and molecular bands. The temperature of the stars is divided in a sequence called OBAFGKM, ranging from the hottest (type O) to the coolest (type M) stars. These spectral types are further subdivided by a decimal system, ranging from 0 (hottest) to 9.5 (coolest). In addition, a luminosity class (from I to V) is assigned to the star, which depends on the intrinsic stellar brightness. That is, the hottest star of the MK system would be of spectral type O0 and the coldest would be a M9 star.

Table 1 illustrates the main properties of each spectral type in the MK standard classification system.

Any classification system should hold a compromise between maintaining the full information of the spectra and the need for a compact sum-