Chapter 12
Connectionist Systems and Signal Processing Techniques Applied to the Parameterization of Stellar Spectra

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ABSTRACT

A stellar spectrum is the finger-print identification of a particular star, the result of the radiation transport through its atmosphere. The physical conditions in the stellar atmosphere, its effective temperature, surface gravity, and the presence and abundance of chemical elements explain the observed features in the stellar spectra, such as the shape of the overall continuum and the presence and strength of particular lines and bands. The derivation of the atmospheric stellar parameters from a representative sample of stellar spectra collected by ground-based and spatial telescopes is essential when a realistic view of the Galaxy and its components is to be obtained. In the last decade, extensive astronomical surveys recording information of large portions of the sky have become a reality since the development of robotic or semi-automated telescopes. The Gaia satellite is one of the key missions of the European Space Agency (ESA) and its launch is planned for 2011. Gaia will carry out the so-called Galaxy Census by extracting precise information on the nature of its main constituents, including the spectra of objects (Wilkinson, 2005). Traditional methods for the extraction of the fundamental atmospheric stellar parameters (effective temperature (Teff), gravity (log G), metallicity ([Fe/H]), and abundance of alpha elements [α/Fe], elements integer multiples of the mass of the helium nucleus) are time-consuming and unapproachable

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for a massive survey involving 1 billion objects (about 1% of the Galaxy constituents) such as Gaia. This work presents the results of the authors' study and shows the feasibility of an automated extraction of the previously mentioned stellar atmospheric parameters from near infrared spectra in the wavelength region of the Gaia Radial Velocity Spectrograph (RVS). The authors' approach is based on a technique that has already been applied to problems of the non-linear parameterization of signals: artificial neural networks. It breaks ground in the consideration of transformed domains (Fourier and Wavelet Transforms) during the preprocessing stage of the spectral signals in order to select the frequency resolution that is best suited for each atmospheric parameter. The authors have also progressed in estimating the noise (SNR) that blurs the signal on the basis of its power spectrum and the application of noise-dependant algorithms of parameterization. This study has provided additional information that allows them to progress in the development of hybrid systems devoted to the automated classification of stellar spectra.

INTRODUCTION

Spectral parameterization is a well-known problem in Astrophysics, and many previous studies have worked with a wide range of data sources (Bailer-Jones, 2008; Christlieb, 2002; Recio-Blanco, 2002; Von Hippel 2002). The purpose of these works was the study of the electromagnetic radiation spectra radiated from stars and other astronomical objects. Spectroscopy can be used to infer most stellar properties and also many attributes of distant galaxies.

Historically, the techniques that have most often been applied to automated spectra parameterization have been artificial neural networks and the minimal distance methods. Various studies have tried to determine the physical parameters of stellar spectra using artificial neural networks (ANN) and synthetic data sets (Kaempf, 2005; Bailer-Jones, 2000; Harrinder, 1998; Allende, 2000; Fiorentin., 2007). The main objective is to ascertain the fundamental stellar atmospheric parameters, particularly effective temperatures, superficial gravities, metallicities, possible over-abundances of alpha elements, and individual abundances of certain chemical elements.

Stellar physico-chemical parameterization represents a fundamental step for the understanding and modelling of the Galaxy and its components. The classification of stars present in a sample or a wide collection of objects is opening new horizons in galactic astrophysics, and is helping to untangle the sequence of phenomena that have led to the present structure of the Via Lactea. The study of the metal content and chemical abundances of wide samples of stars is providing evidence on the history of stellar formation and information on the chemical enrichment from previous populations, with a detail that was inimaginable before. The Gaia ESA space mission was designed as a primarily astrometric mission that will extend the Hipparcos mission legacy with several orders of magnitude, both with respect to astrometric precision and the number of observed sources. But Gaia is a complex project, conceived to provide much more information about the Galaxy and its vicinity. It will take back two spectrophotometers that will measure the spectral energy distributions of the observed sources (between 330 and 1050 nm) and will allow us to determine their physical nature. It will also be equipped with a radial velocity spectrograph (RVS), designed to determine radial velocities and stellar parameters up to magnitude 17 (approximately) with a resolution of R=11500, and an operative wavelength range around the near IR CaII triplet (847 to 874 nm). Our study focuses on the preparation of automated analysis tools for the RVS survey.

The Gaia satellite, which is foreseen to be launched near the end of 2011, is one of the present key scientific missions of the European Space Agency (ESA). The Gaia mission will carry out

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