Mem. S.A.It. Vol. 76, 89

Memorie della

An inverse method for stellar population synthesis: Application to AGN

J. Moultaka

I.Physikalisches Institut, Universität zu Köln, Zülpicher str. 77, 50937 Köln, Germany

Abstract. I present a new inverse method for stellar population synthesis in unresolved galaxies. This method provides the unique solution that fits at best a composite object spectrum using a database of stellar (or clusters) spectra. It provides as well an estimation of the error around the solution giving thus a confidence level to the result. The reddening in the optical spectrum due to the presence of dust, the dust emission in the IR, the continum emission of an AGN and the velocity dispersion of stars are also modelled. This method (described in Moultaka 2004, in press) is thus a powerful tool for the study of the stellar composition of unresolved galaxies, especially at high specral resolution.
The method is applied to a sample of previously studied AGNs. It provides very satisfactory results.

Key words. Stellar population synthesis – inverse methods – AGN

1. Introduction

The problem of "stellar population synthesis" is to derive the stellar population of an unresolved stellar system using a database of stars or clusters.

Two approaches have been proposed in order to solve this problem: *1-The direct approach* or "the evolutionary synthesis methods" where an a priori model of stellar population is defined and used to fit the observations; *2- The inverse approach* or "the inverse synthesis methods" where no a priori assumption is made on the stellar population history. In this approach, one uses exclusively the observations to derive the present stellar population.

In both cases, the problem is "ill-posed" (i.e. no solution, no unique solution or no stable solution is necessarily available). Thus a rigorous analysis and a careful interpretation of a solution are essential when dealing with this problem.

2. The method

First we consider a simple model where a galaxy is only composed of stars. The synthetic spectrum is then obtained from the synthetic equation:

$$I_{syn} = \sum_{i=1}^{n_\star} k_i I_{ji} \tag{1}$$

where I_{ji} are the class i (i.e. spectral type and luminosity class) stellar intensities at wavelength λ (indexed with j) normalised to the intensity at a reference wavelength λ_0; k_i are the contributions to luminosity at a reference wavelength λ_0 of stars of class i and $n_\star$ is the number of stars (or clusters) considered in the database.

The synthesis problem is then solved by minimising the objective function called the "synthetic distance" as defined by Pelat (1997):

$$D^2 = f(k) = \sum_{j=1}^{n_l} (I_{gal\,j} - \sum_{i=1}^{n_\star} k_i I_{ji})^2 = \sum_{j=1}^{n_l} (I_{gal\,j} - I_{syn\,j})^2 \quad (2)$$

where $I_{gal\,j}$ are the galactic observed n_l intensities of the spectrum and where the contributions to luminosity k_i (the n_l components of vector k) are subject to linear constraints written as follows:

$$\boldsymbol{l} \leq \left\{ \begin{array}{c} \boldsymbol{k} \\ \boldsymbol{Ck} \end{array} \right\} \leq \boldsymbol{u} \quad (3)$$

In the previous equation, l and u are respectively lower and upper constant vector limits and C is the constraint matrix. This equation takes into account the positivity constraint of the contributions to luminosity k_i.

The constraints allow us to obtain better solutions satisfying physical conditions as the shape of the IMF.

The synthesis problem comes then to be a least-square problem possessing a unique solution.

A rigorous analytical computation of the error bars (Δk_i) around a solution (i.e. around the contributions to luminosity) is also provided (see details in Moultaka, 2004, in press). The computed uncertainties provide an estimation of the stability of the solution with a reasonable computing time, which is not the case when Monte-Carlo simulations are performed.

Dust emission in the IR or AGN continuum emission are then included as additional spectra in the database (the spectrum of a dust emission law with a given temperature in the first case and the spectrum of a power law with a given index in the case of AGN contribution). The synthesis is repeated with different temperatures or indices and the retained solution is the one that minimises the synthetic distance.

The velocity dispersion of stars and the reddening, E(B-V), due to the presence of dust along the line of sight are also modeled by testing different databases constructed from the initial database with different reddenings and velocity dispersions. The solution providing the smallest synthetic distance is retained with the corresponding values of E(B-V) and velocity dispersion.

3. Test of the method and application to AGNs:

The method was tested on simulated galaxies of different ages, metallicities, velocity dispersions and reddening. The results show that when the Signal to Noise ratio at each pixel goes to infinity, the solution provides the exact population and a population quite well-defined (more than 2-σ error) when this ratio is larger than 50.

The application of the method to the sample of optical medium resolution spectra of 12 active galaxies from Boisson et al. (2000) has shown that the global solutions obtained with this method agree well with those of the previous paper.

As discussed in Boisson et al. (2000), the obtained results show that there are no main differences in the stellar populations between the host galaxies and normal galaxies of same morphology. However, the stellar compositions of Starburst galaxies (SB), Seyfert2s and LINERs suggest an evolutionary sequence between these classes.

New analyses of the stellar populations of active galaxies especially in the NIR and in the blue at high spectral resolution should be done in order to confirm or invalidate the evolutionary sequence and to shed light on the mostly debated SB/AGN connection.

References

Boisson C. et al. 2000, A&A 357, 850
Moultaka J. & Pelat D., 2000, MNRAS 314, 409
Moultaka J. et al. 2004, A&A 420, 459
Pelat D., 1997, MNRAS 284, 365