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CONSTRAINING THE EVOLUTIONARY HISTORIES OF SPIRAL DISKS

M. Mollá

Departamento de Física Teórica C-XI, Universidad Autónoma de Madrid
Campus de Cantoblanco, E-28049 Madrid, Spain

and E. Hardy

National Radio Astronomy Observatory (NRAO)
Casilla 36-D, Santiago, Chile

We study the old problem of the uniqueness of chemical evolution models. We showed in Mollá et al. (1999) that multiphase models for three Virgo cluster galaxies were able to reproduce the observed radial distributions of spectral indices Mg2 and Fe52. But those models may fit the present-epoch radial distributions with different star formation histories (Tosi 1996). The two spectral indices above are in turn affected by the well known age–metallicity degeneracy which prevents the disentangling of age and metallicity for single stellar populations. In this work we face both issues by analyzing a set of multiphase models for the Virgo galaxy NGC 4303.

1. INTRODUCTION

In this study we compute a large number of multiphase chemical evolution models for the Virgo galaxy NGC 4303. This model has been widely described in Ferrini et al. (1994); Mollá et al. (1999). A protogalaxy is assumed to be a spheroid composed of primordial gas with total mass $M(R)$. For NGC 4303 the rotation curves obtained by Distefano et al. (1990) and (Guhathakurta et al. 1988) are used to compute $M(R)$. The galaxy is divided into concentric cylindrical regions 1 kpc wide and the model calculates the time evolution of the halo and disk components belonging to each one. The halo gas falls into the galactic plane to form the disk, which is a secondary structure in this scenario, at a rate f. This infall rate f is inversely proportional to the collapse timescale $\tau_{\rm coll}$, which, in turn, is assumed to depend on galactocentric radius as: $\tau_{\rm coll} = \tau_0 \exp{(R-R_0)}/\lambda_D$, where the characteristic timescale τ_0 is determined using the total mass of the galaxy, through the expression (Gallagher et al. 1984):

$$\tau_0 = \tau_{\rm MWG}(\frac{M_{9,\rm MWG}}{M_{9,\rm gal}})1/2. \qquad (1)$$

Stars form out in the halo, by a Schmidt law, while in the disk stars form in two steps: molecular clouds c form from the diffuse gas by a Schmidt law, $c = \mu g^{1.5}$, then cloud–cloud collisions produce stars by a spontaneous process, at a rate proportional to H: $SFR \propto Hc2$. The efficiencies or probabilities to form molecular clouds and stars, ϵ_μ and ϵ_H respectively, are assumed as dependent on morphological type, T (see Mollá et al. 2002). The other two efficiencies corresponding the other processes described are assumed constant for all haloes and galaxies.

2. THE COMPUTED MODELS

We must now select these input parameters (τ_0,λ_D and T) for this galaxy. In order to take into account the uncertainties in their selection, we choose them over a wide range of values. We thus run models with five values for the characteristic collapse timescale: τ_0 =1, 4, 8, 12 and 16 Gyr. We also assume five possible values for the scale length: λ_D =1, 4, 8, 12 and 16 kpc. On the other hand, if we change the collapse timescale values, the efficiencies — or equivalently T — must be changed accordingly in order to reproduce the observed radial distributions which are the same used in (Mollá et al. 1999). We assume that T take values from 1 to 20. We thus run a total of 500 models with all possible variations of these three parameters, τ_0 , λ_D and T.

3. THE χ^2 OPTIMIZATION

We estimate the goodness of fit for these 500 models with the statistical indicator χ^2 (see Mollá & Hardy 2002 for details). First, by choosing those models able to fit the present-time observational constraints with probabilities larger than 97.5%, we find only nineteen valid models among the 500 initial ones.

Next, radial distributions of Mg2 and Fe5270 are computed, by using the chemical abundances and star formation histories predicted by the above selected chemical evolutionary models as the necessary

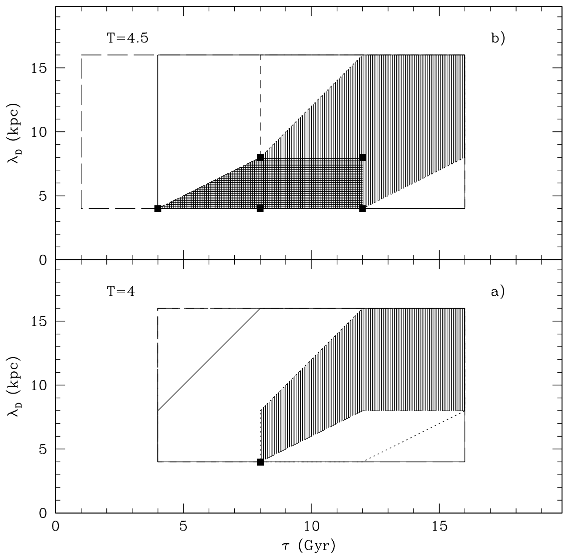

Fig. 1. Probability contours representing regions with $P \geq 97.5$ % for all observational constraints for $T = 4$ (panel a) and $T = 4.5$ (panel b) as a function of τ and λ.

input for the synthesis procedure which calculates spectral indices. We use again the statistical indicator χ^2 to compare these predicted spectral indices distributions with the data and thus to select the adequate evolutionary histories over the disk. Only six models are able to fit the spectral indices' radial distributions with the same level of confidence of 97.5%.

We reduce, therefore, the possible star formation histories to those predicted by the models whose parameters fall within a very restricted range: $4 < T < 4.5$, $4 < \tau_0 < 12$ and $4 < \lambda_D < 8$. This may be clearly seen in Figure 1, where the regions with probabilities higher than 97.5% for all observational constraints are shown as the zones shaded with horizontal and vertical lines for $T = 4.5$ (panel b), while for $T = 4$ (panle a) there is only one point ($\tau_0 = 8$ Gyr, $\lambda_D = 4$ kpc).

4. CONCLUSIONS

- When spectral indices are used these nineteen possibilities reduce to six. The spectrophotometric information is essential to select the appropriate star formation histories.
- Our technique of mixing both evolutionary chemical and synthesis models proves to be a very useful tool that might be applied to other kinds of galaxies or galaxy regions.
- We suggest that radial measurements of spectral indices on spiral disks must be considered seriously in the preparation of observing programs.

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