POPULATION SYNTHESIS IN NEARBY AND DISTANT GALAXIES

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The properties of large assemblies of stars in galaxies mirror the mechanisms of galaxy formation and evolution. The aims and companion techniques are different passing from our own galaxy (the Milky Way), to galaxies of the Local Group that can easily resolved into stars, and the distant galaxies for which only integrated properties can be measured. Therefore the program splits in several parts dedicated to different yet similar aims:

(1)The 3D structure of the Milky Way. The project is framed in the future GAIA mission aimed at providing accurate distances for one billion stars in the Galaxy so that the reconstruction of the present and past structure and hence formation and evolutionary histories for the various components will be possible.

(2) Resolved stellar populations in nearby galaxies.
The aim of this project is to decipher the extremely rich Color Magnitude Diagrams (CMDs) and Luminosity/Color Functions (L/CF that are currently available for the stellar content of nearby galaxies (Local Group) by means of the Simulated CMD and L/CFs technique which is the analogue of what is also made for the Milky Way. The results are the histories of star formation and chemical enrichment in the target galaxies. Studies of this type have been started long ago and proceed thanks to the unprecedented quality and richness of the data samples. The method is very robust and the quality of the

(3) Ages, metallicities and abundance ratios in early type galaxies.
Broad band magnitudes, colors, absorption line indices and spectral energies distribution for the pattern of stellar population in a galaxy are the fossil records of their past and present history of star formation and chemical enrichment wich in drive and depend on the overall process of galaxy formation thanks to which dark matter aggregating in structures of different complexity buld up the graviatational potential well inside which barions collapse to form stars, i.e. the luminous galaxy we see today. Therefore extracting the age, the metallicity and the abundance ratios puts strong constraints on the star formation history and its time scale. This casts light of the formation process itself.

(4) Effects of the dust on the spectral energy distribution of galaxies.
The advent of modern infrared astronomy has brought into evidence the role played by the interstellar dust in the subject of galaxy formation and evolution. Therefore, to fully exploit modern data, galactic spectro-photometric models must include the dusty component of the interstellar medium and take into account all recent advancements in dust models. To this aim we construct a new generation of chemo-spectro-photometric models of galaxies of different morphological type containing three interacting components: the diffuse interstellar medium, made of gas and dust, the large complexes of molecular clouds in which active star formation occurs and, finally, the populations of stars. These latter can in turn be no longer embedded in the dusty environment in which they form like O-type abd AGB stars, and naked objects. The most relevant effect of dust is to absorb the light emitted by stars in the UV/optical region of the spectrum and to re-emit it in the mid/far infrared. The resulting spectral enrgy distribution is the one to be compared with observational data.

For each project we report on recent achievements and when appropriate we shortly summarize the scientific rationale and outline the future plans.

Project 1: 3-D STRUCTURE OF THE MILKY WAY

(1) Ng Y.K, Broght E, Chiosi C., Bertelli G. *Automatic observation rendering (AMORE).I. On a synthetic stellar population's colour-magnitude diagram.* (2002). ASTRONOMY & ASTROPHYSICS. vol. 392, pp. 1129-1147

A new method, AMORE - based on a genetic algorithm optimizer, is presented for the automated study of colour-magnitude diagrams. The method combines several stellar population synthesis tools developed in the last decade by or in collaboration with the Padova group. Our method is able to recover, within the uncertainties, the parameters - distance, extinction, age, metallicity, index of a power-law initial mass function and the index of an exponential star formation rate - from a reference synthetic stellar population. No a priori information is inserted to recover the parameters, which is done simultaneously and not one at a time. Examples are given to demonstrate and to better understand biases in the results, if one of the input parameters is deliberately set fixed to a non-optimum value.

(3) Bertelli G., Nasi E. *Star Formation History in the Solar Vicinity. (2001)*. The Astronomical Journal, Volume 121, Issue 2, pp. 1013-1023.

The star formation history in the solar neighborhood is inferred by comparing a sample of field stars from the Hipparcos catalog with synthetic color-magnitude diagrams. We consider separately the main sequence and the red giant region of the H-R diagram. The criteria for our best solutions are based on the chi^2 minimization of star distributions in selected zones of the H-R diagram. Our analysis suggests (1) that the solutions are compatible with a Salpeter initial mass function and with a star formation rate increasing in a broad sense from the beginning to the present time, (2) that the deduced volume-mass densities and the corresponding absolute scale of the star formation rate solutions are strongly influenced by the initial mass function slope of low-mass stars (below 0.5 M_o), and (3) that the stellar evolutionary models are not completely adequate: in fact the theoretical ratio between the He-burning and MS star numbers is always a factor of 1.5 greater than the observational value. This fact could indicate the need for a more efficient overshoot in the evolutionary models or a different mixing theory.

(3) VallenariA., Bertelli G., Chiosi C., Nasi E., Pasetto S., Carraro G. *3-D structure of the Galaxy from star counts.* (2003). MEMORIE DELLA SOCIETA' ASTRONOMICA ITALIANA. vol. 74, pp. 522

(4) Ragaini S., Vallenari A., Bertelli G., Chiosi C. *The inner Galactic Bulge.* (2004). MEMORIE DELLA SOCIETA' ASTRONOMICA ITALIANA. vol. 5, pp. 283-288

(5) Katz, D.; Munari, U.; Cropper, M.; Zwitter, T.; Thévenin, F.; David, M.; Viala, Y.; Crifo, F.; Gomboc, A.; Royer, F.; and 40 coauthors. *Spectroscopic survey of the Galaxy with Gaia- I. Design and performance of the Radial Velocity Spectrometer* . (2004). MNRAS Volume 354, Issue 4, pp. 1223-1238.

The definition and optimization studies for the Gaia satellite spectrograph, the `radial velocity spectrometer' (RVS), converged in late 2002 with the adoption of the instrument baseline. This paper reviews the characteristics of the selected configuration and presents its expected performance. The RVS is a 2.0 × 1.6 degree integral field spectrograph, dispersing the light of all sources entering its field of view with a resolving power $R=\lambda/D\lambda= 11500$ over the wavelength range [848, 874] nm. The RVS will continuously and repeatedly scan the sky during the 5-yr Gaia mission. On average, each source will be observed 102 times over this period. The RVS will collect the spectra of about 100-150 million stars up to magnitude V~= 17-18. At the end of the mission, the RVS will provide radial velocities with precisions of ~2 km s^{-1} at V= 15 and ~15-20 km s^{-1} at V= 17, for a solar-metallicity G5 dwarf. The RVS will also provide rotational velocities, with precisions (at the end of the mission) for late-type stars of $\sigma_{\varpi \sin i}$~= 5 km s^{-1} at V~= 15 as well as atmospheric parameters up to V~= 14-15. The individual abundances of elements such as silicon and magnesium, vital for the understanding of Galactic evolution, will be obtained up to V~= 12-13. Finally, the presence of the 862.0-nm diffuse interstellar band (DIB) in the RVS wavelength range will make it possible to derive the three-dimensional structure of the interstellar reddening.

(6) Wilkinson, M. I.; Vallenari, A.; Turon, C.; Munari, U.; Katz, D.; Bono, G.; Cropper, M.; Helmi, A.; Robichon, N.; Thévenin, F.; and 31 coauthors. *Spectroscopic survey of the Galaxy with Gaia- II. The expected science yield from the Radial Velocity Spectrometer.* (2005). MNRAS, Vol. 359, Issue 4, pp. 1306-1335.

The Gaia mission is designed as a Galaxy explorer, and will measure simultaneously, in a survey mode, the five or six phase-space parameters of all stars brighter than 20th magnitude, as well as providing a description of their astrophysical characteristics. These measurements are obtained by combining an astrometric instrument with micro-arcsecond capabilities, a photometric system giving the magnitudes and colours in 15 bands and a medium-resolution spectrograph named the Radial Velocity Spectrometer (RVS). The latter instrument will produce spectra in the 848- to 874-nm wavelength range, with a resolving power R= 11500, from which radial velocities, rotational velocities, atmospheric parameters and abundances can be derived. A companion paper has presented the characteristics of the RVS and its performance. The present paper details the outstanding scientific impact of this important part of the Gaia satellite on some key open questions in present-day astrophysics. The unbiased and simultaneous acquisition of multi-epoch radial velocities and individual abundances of key elements in parallel with the astrometric parameters is essential for the determination of the dynamical state and formation history of our Galaxy. Moreover, for stars brighter than V~= 15, the resolving power of the RVS will give information about most of the effects that influence the position of a star in the Hertzsprung-Russell diagram, placing unprecedented constraints on the age, internal structure and evolution of stars of all types. Finally, the RVS multi-epoch observations are ideally suited to the identification, classification and characterization of the many types of double, multiple and variable stars.

Rationale of the whole project and future plans

One of the challenges of modern astrophysics is to cast light on the complexity of the galaxy formation and evolution process. The diagnostic is hidden in the properties of stellar populations (SP): position, kinematics, age, and chemical composition. Positions and kinematics are the fossil records of the dynamical processes, ages and chemical composition are the tracers of the star formation history.

While deriving ages and abundances for large samples of stars is currently feasible thanks to instrumental developments and population synthesis achievements, determining positions and kinematics for large numbers of objects is still a cumbersome
affair. As matter of fact, astrometric parallaxes of high precision (<10%) are available for some 20000 stars in the solar vicinity (Tycho, Hipparcos). Furthermore, radial velocities with precision less than 50% exist only for 10000 stars (cf. CDS/SIMBAD). The body of kinematical information stems from tracers (RR-Lyrae, K giants,F-G dwarf, globular clusters....), each of these being however only partially representative of the population it belongs to.

Fortunately, the situation is rapidly improving. In a near future, the GSC-2 and GSPC-2 catalogs will provide photometric and astrometric data for one billion stars in the Milky Way, whereas the RAVE survey will yield radial velocities of high precision (2 km/s) for all stars visible in the sky down to the V=15.5 magnitude. Given this large number of stars with known velocity and position, the present and past structure of the Milky Way will be unraveled. Finally GAIA will set the ground for very accurate positions and distances of an unprecedented large sample of stars.

The most credited scenario for the formation of the Milky Way stands on both the initial collapse of Baryonic Matter into the potential well of Dark Matter (Eggen et al. 1962) and the aggregation of smaller objects made of either stars or gas(Searle & Zinn 1978, Peebles 2000). In this context, the Milky ay grows around a central body (most likely the Bulge) and accreting matter in later epochs forms the external halo and the disc (Gilmore & Wyse 2001). The major difficulty with this scheme is the scale length of the disc: against an expected value of 300 pc, observations show 3 kpc (Steinmetz & Navarro 1999). How to probe this models and/or to constrain it? If mergers/captures had such an important role, we must find the fossil relics of those events (such as age, metallicity, velocity differences and streaming motions) and determine the age at which they occurred. To this aim, the analysis of CMDs, luminosity functions, chemical abundances for large samples of stars belonging to different SPs must be combined with that of kinematics and dynamics. As matter of fact, the present position of a star in the Galaxy may be different from the one at the birth; dynamical instabilities of disc may mix the stars in the phase-space; the bar instabilities may induce gas motions and novel star formation; the bulge my be formed by accretion or disc/bar instabilities.

The probable, simultaneous existence of the thick (Thick-D) and thin disc (Thin-D), the former kinematically hotter than the latter, may be caused by heating of a pre-existing Thin-D (by mergers/interactions with satellite galaxies) or cooling of the Thick-D to form the Thin-D (Wyse 2002). Dissipation models of formation predict nearly identical chemical gradients and scale lengths for both Thin-D and Thick-D (Burkert et al. 1992). Formation by mergers/accretions implies that stars with different kinematics (lower rotation velocity and higher dispersion velocity) must co-exist. Furthermore, since radial mixing far from the Galactic Plane is poorly efficient,chemical and/or kinematical gradients ought to remain in the Thick-D (Freeman & Bland-Hawthorn 2002). Finally, the scale lengths of the Thin-D and Thick-D are likely different. From an observational point of view, neither the age nor the metallicity of the Thick-D are assessed. This indeed could contain two components of high and low metallicity (Soubiran et al. 2003). Large uncertainties exist also for the length and height scales. As far as kinematics is concerned, on one hand velocity gradients perpendicular to the Galactic Plane are excluded (Soubiran et al. 2003 and references), on the other hand it is suggested that the rotational velocity decrease and the dispersion velocity far from the disc, with a velocity gradient of about 30 km/s/kpc (Chiba & Beers 2000). Finally a multi-component structure with tracers of mergers/accretions has been suggested by Gilmore et al. (2002). Simulations of CMDs and phase space of the RAVE and GSPC2.3 data could cast light on those issues.

The Thin-D keeps memory of the proto-galaxy initial conditions. As matter of fact its scale length and surface density gradients are reminiscent of the initial angular momentum and mass of the baryonic proto-cloud (de Jong & Lacey 2000). In contrast the scale height could depend on interactions between stars and gas clouds. Current observational data do not provide a clear hint for the scale length and scale height and the existence of a cut-off radius at 12-14 kpc from the centre (e.g. Vallenari et al. 2000). The Thin-D kinematics is poorly known: the structure of the velocity ellipsoid, its deviation and inclination parallel and perpendicular to the Galactic Plane rest on a small sample of local stars. Soubiran et al. (2002 and references) suggest a vertex deviation going from 25 a 0 degrees at varying age. Lewis & Freman (1998) argue that a gradient in velocity dispersion ought to exist. The age-velocity dispersion relationship is based on a sample of about

200 stars in the solar vicinity and seems to hold only forages younger than about 3 Gyr (e.g. Quillen & Garnett 2001). All this needs to be confirmed.

The Galactic Bulge is likely barred or triaxial (e.g. Mao & Packzynski 2002 and references). Inclination and mass of the bar, and motions of the stars within it are basically unknown (e.g. Ibata & Gilmore 1995). Star counts suggest that the Bulge has azimuthal simmetry inside 1 kpc and oblate shape outside (Alard 2001). Realistic kinematical models are very difficult to calculate (e.g. Fux 2001 and references). Simulations of the CMDs and proper motions might cast light on the problem. Finally, the age distribution of the stars in the Bulge is very uncertain: only very old stars (10-15 Gyr) or with a tail of younger objects down to ages of about 1-2 Gyr (e.g. van Loon et al. 1999 and references)?

Chemical gradients, dispersion in the [Fe/H] ratio, and [alpha/Fe] abundance ratios allow us to infer the ages of the SPs and to determine the time scale ofthe formation process. Currently, the age-metallicity relationship of the Galactic SPs is poorly known. Suffice it to mention that it is a matter of debate whether an age-metallicity relation exists for the stars in the Thin-D (e.g. Ibukiyama & Arimoto 2002, Feltzing et al. 2001 and references). The RAVE data for abundances together with ages derived from CMDs will surely highlight the existence and nature of the age-metallicity relationship.

The CMDs of Galactic stellar fields are the result of a complex game of many players among which we recall the dynamical processes that led to the formation of various structures of the galaxy: bulge, halo, disc; the history of star formation, the distribution of ages chemical chemical abundances of the component GSPs, the mass distribution along the line of sight determined by the different components, the extinction, the kinematics of the stars entering and leaving the various volumes of space under examination, etc. The Padova Software Telescope simulates observed CMDs taking into account the geometry of the system, the spatial distribution of matter (stars of any mass, age and chemical abundances), the star formation history and the spatial variation of the extinction. The Software Telescope has successfully been applied in a series of studies meant to reconstruct the structure of the Milky Way (Ng et al. 1995; Bertelli et al. 1997, 1999; Vallenari et al 1999a,b,c; Vallenari et al. 2000; Vallenari & Ortolani 2001; Vallenari et al. 2003). The current version of this is hampered by the limited number of stars to be handled (up to about 100000) and in the mathematical algorithm in use to check the uniqueness of the solution.

The most recent version of the Software Telescope is also able to deal in self-consistent fashion with both CMDs and proper motions and radial velocities for the stars in the thin disc, halo, and bulge (Bertelli et al. 2003). Particular care is given to develop a kinematical model of the thin disc. The method in use stands on the study by Amendt & Cuddeford (1991, ApJ 368,79) and takes the vertical tilt of the velocity ellipsoid as function of the Galactic potential into account. The model provides a good description of the stellar kinematics up to large distances above the Galactic Plane.

The Galaxy model we have proposed has been applied to simulations of the GAIA data to better define the detectors on board that will provide the best data (both photometric and spectroscopic) for the GSPs (Bertelli et al. 2003). We also plan to improve upon the kinematical description of the thin disk and to do the same for the bulge by means of an analytical formulation.

Project 2: RESOLVED STELLAR POPULATIONS IN NEARBY GALAXIES

(1) Marigo P., Girardi L., Chiosi C. **The red tail of carbon stars in the LMC: Models meet 2MASS and DENIS observations.** ***(2003). Astronomy & Astrophysics 403, pp. 225-238***

Carbon stars are known to exhibit systematically redder near-infrared colours with respect to M-type stars. In the near-infrared colour-magnitude diagrams provided by the 2MASS and DENIS surveys, the LMC C-type stars draw a striking red tail, well separated from the sequences of O-rich giants. So far, this conspicuous feature has been absent from any set of available isochrones, even the few existing ones that include the TP-AGB evolution of low- and intermediate-mass stars. To investigate such issue we simulate the complete 2MASS Ks vs.(J-Ks) data towards the LMC by means of a population synthesis approach, that relies on extended libraries of published stellar evolutionary tracks, including the TP-AGB phase. The simulations provide quite a detailed description of the several vertical fingers and inclined sequences seen in 2MASS data, due to both Galactic foreground and LMC O-rich stars. Instead, as mentioned, the red tail of C-stars sets a major difficulty: we find that TP-AGB models with solar-scaled molecular opacities, the usual assumption of existing AGB calculations, do not succeed in reproducing this feature. Our tests indicate that the main reason for this failure should not be ascribed to empirical Teff - (J-K) transformations for C-type stars. Instead, the discrepancy is simply removed by adopting new evolutionary models that account for the changes in molecular opacities as AGB stars get enriched in carbon via the third dredge-up (Marigo 2002). In fact, simulations that adopt these models are able to reproduce, for the first time, the red tail of C-stars in near-infrared CMDs. Finally, we point out that these simulations also provide useful indications about the efficiency of the third dredge-up process, and the pulsation modes of long-period variables.

(2) Rizzi L., Held E., Bertelli G., Saviane I. ***Clues to the Evolution of the Carina Dwarf Spheroidal Galaxy from the Color Distribution of its Red Giant Stars.*** **(2003). The Astrophysical Journal, Volume 589, Issue 2, pp. L85-L88.**

The thin red giant branch (RGB) of the Carina dwarf spheroidal galaxy appears at first sight quite puzzling and seemingly in contrast to the presence of several distinct bursts of star formation. In this Letter, we provide a measurement of the color spread of red giant stars in Carina, based on new BVI wide-field observations, and model the width of the RGB by means of synthetic color-magnitude diagrams. The measured color spread, sigma$_{V-I}$=0.021+/-0.005, is quite naturally accounted for by the star formation history of the galaxy. The thin RGB appears to be essentially related to the limited age range of its dominant stellar populations, with no need for a metallicity dispersion at a given age. This result is relatively robust with respect to changes in the assumed age-metallicity relation, as long as the mean metallicity over the galaxy lifetime matches the observed value ([Fe/H]=-1.91+/-0.12 after correction for the age effects). This analysis of photometric data also sets some constraints on the chemical evolution of Carina by indicating that the chemical abundance of the interstellar medium in Carina remained low throughout each episode of star formation even though these episodes occurred over many gigayears. Based on data collected at ESO La Silla, Chile, proposals 63.N-0017 and 64.N-0512.

Project 3: AGES, METALLICITIES AND ABUNDANCE RATIOS OF EARLY TYPE GALAXIES

(1) Tantalo R. & Chiosi C. ***Enhancement of α–elements in dynamical models of elliptical galaxies*** **(2002). ASTRONOMY & ASTROPHYSICS. vol. 388, pp. 396-406**

There is still much disagreement among the astronomical community on both the process of formation and evolution of early-type galaxies. Are EGs formed in a single collapse during a short epoch of activity (monolithic scheme) or continuously by hierarchical mergers at similar levels by several mergers (hierarchical scheme)? Once created, is the stellar population of EGs just passively evolving or do minor merging/accretion events drastically change their characteristics frequently? What is the influence of density environment? In the monolithic scenario EGs are supposed to suffer dominant star forming activity and consequent chemical enrichment at very early epochs followed by quiescent evolution, marginal episodes of star formation of both internal and external origin may occur under suitable circumstances (e.g. interactions). In the hierarchical scenario EGs are supposed to be formed by mergers (one to several) of smaller units, each episode inducing star formation and chemical enrichment. Both scenarios are able to reproduce only part of the observed properties of EGs. For instance the ``monolithic scheme'', cannot account for the wide morphological and kinematical variety of EGs, for instance the presence of counter-rotating cores, small disks and recent stellar activity .In contrast, despite its success in modeling the dynamical structure of EGs, the ``hierarchical scenario'' does not predict the whole pattern of chemical properties. Indeed, EGs often have different ratios between the abundances of some chemical species. They are in general more metal-rich and enhanced in α-elements with respect to spiral galaxies. In the merging scenario this could be justified by an additional chemical enrichment with strong enhancement in a-elements. See the reviews by Chiosi (2001}. Recently Chiosi & Carraro (2002) have investigated by means of N-Body, Tree-SPH models whether the monolithic scheme of galaxy formation and evolution may interpret the observational properties of EGs. They have studied in particular how the history of star formation depends on the initial conditions (density) and/or mass of the proto-galaxy showing that the monolithic scheme can indeed reproduce many fundamental properties of EGs, such as colors, mass to light ratios, the color magnitude relation (CMR), and the so-called Fundamental Plane. In this study we derive the present-day level of enhancement in a-elements in the Chiosi & Carraro (2002) models, cast light on the main cause of it, derived the mean spectral indices of the model galaxies, and compared them to the observations with particular attention to the Mg_2-σ relation and the Hβ-Mg_2--[MgFe] planes. The main conlcusions are: (i) The star formation history of EGs as predicted by Chiosi & Carraro (2002) is fully compatible with the pattern of abundances and degree of enjancement in a-elements shown by EGs that seems to increase with galaxy velocity dispersion (and hence mass and luminosity) of the galaxy (ii) The Mg_2 vs σ relation mainly reflects the metallicity-σ-mass sequence rather than enhancement in a-elements and/or age.

(2) Tantalo R. & Chiosi C. ***Measuring age, metallicity and abundance ratios from absorption line indices.*** **(2004). MNRAS, vol. 353, pp. 917-941**

In this study we present detailed calculations of absorption line indices on the Lick System based on the new stellar models by \citet{Salasnich20} incorporating the enhancement of \alfa\ both in the opacity and in the chemical abundances. The models span large ranges of initial masses, chemical compositions, and ages, and are calculated for both solar and enhanced abundance ratios [X_{el}/Fe] of α-elements. With these models and the so-called Response Functions of Tripicco & Bell (1995), we calculate the indices for Single Stellar Populations (SSPs) of different age, metallicity and degree of enhancement. Starting from the widely accepted conviction that Hβ is a good age indicator, that [MgFe] is most sensitive to metallicity, and indices like Mgb, Mg2and others are most sensitive to metallicity and degree on enhancement, we made use of the triplet Hβ, Mgb and [MgFe], and Minimum-Distance Method proposed by Trager et al 2000 to estimate the age, metallicity and enhancement degree for the galaxies of the Gonzalez (1993) sample, and compare the results with those by Trager et al. (2000) and Thomas et (2003}. Since very large differences are found, in particular as far as the age is concerned, ours are systematically older than those of Trager et al. (2000}) and Thomas et al (2003), we analyze in a great detail all possible sources of disagreement, going from the stellar models and SSPs to many technical details of the procedure to calculate the indices, and finally the pattern of chemical elements (especially when α-

enhanced mixtures are adopted). Each of the above aspects of the problem bears on the final result: amazingly enough, at increasing complexity of the underlying stellar models and SSPs, the uncertainty increases. However, the key issue of the analysis is that at given metallicity Z and enhancement factor, the specific abundance ratios [X_el/Fe] adopted for some elements (e.g. O, Mg, Ti, and likely others) dominate the scene because with the Tripicco & Bell (1995) Response Functions they may strongly affects indices like Hβ and the age in turn. In brief, with the ratio [Ti/Fe]=0.63 adopted by Salasnich et al (2000), Hβ at old ages turned out to larger than the mean observational value, and therefore the age was forced to very old values in order to recover the observations. In contrast, the results by Trager et al. (2000} and Thomas et al. (2003} are immediately recovered if their [Ti/Fe] ratios are adopted, i.e. [Ti/Fe]=0 or 0.3, respectively. We have also analyzed how the galaxy ages, metallicities and degrees of enhancement vary with the triplets of indices in usage. To this aim we turn to the Trager `` IDS Pristine'' sample which contains many more galaxies and a much wider list of indices than the Gonzalez sample. The solution is not unique in that reflecting the poor ability of most indices to disentangle among the three parameters. Finally, at the light of the above results and points of uncertainty, we have drawn some remarks on the interpretation of the distribution of early type galaxies in popular two-indices planes, like Hβ vs. [MgFe]. We argue that part of the scatter along the Hβ axis observed in this plane could be attributed instead of the age, the current explanation, to a spread both in the degree of enhancement and some abundance ratios. If so, another dimension is added to the problem, i.e. the history of star formation and chemical enrichment in individual galaxies. The main conclusion of this study is that deriving ages, metallicities and degree of enhancement from line indices is a cumbersome affair whose results are still uncertain.

(3) Tantalo R. & Chiosi. C. ***Star Formation History in Early-Type Galaxies.I. The Line Absorption Indices Diagnostics*****. (2004). MNRAS vol. 353, pp. 405-421**

To unravel the formation mechanism and the evolutionary history of Elliptical Galaxies (EGs) is one of the goals of modern astrophysics. In a simplified picture of the issue, the question to be answered is whether they have formed by hierarchical merging of pre-existing sub-structures (maybe disc galaxies) made of stars and gas, each merging event likely accompanied by strong star formation, or conversely, they originated from the early aggregation of lumps of gas turned into stars in the remote past via a burst-like episode ever since followed by quiescence so as to mimic a sort of monolithic process. Even if the two alternatives seem to oppose each other, actually they may concur to shaping the final properties of EG's as seen today. Are there distinct signatures of the underlying dominant process in the observational data? To this aim we have examined the line absorption indices on the Lick system of the normal, field EGs of Trager (1997 and the interacting EGs (pair- and shell-objects) of Longhetti et al (2000). The data show that both normal, field and interacting galaxies have the same scattered but smooth distribution in the Hβ vs. [MgFe] plane even if the interacting ones show a more pronounced tail toward high Hβ values. This may suggest that a common physical cause is at the origin of their distribution. There are two straightforward interpretations of increasing complexity: (1) EGs span true large ranges of ages and metallicities. The age youth is the signature of the aggregation mechanism, each event accompanied by metal enrichment. This simple scheme cannot, however, explain other spectro-photometric properties of EGs and has to be discarded. (2) The bulk population of stars is old but subsequent episodes of star formation scatter the EGs in the diagnostic planes. However, this scheme would predict an outstanding clump at low Hβ values, contrary to what is observed. The model can be cured by supposing that the primary star formation activity lasted for a significant fraction of the Hubble time (5 Gyr < T < 13 Gyr) accompanied by global metal enrichment. The ``younger'' galaxies are more metal-rich. The later burst of star formation should be small otherwise too many high Hβ objects would be observed. Therefore, the distribution of normal, pair- and shell-galaxies in the Hβ vs. [MgFe] plane is due to the global metal enrichment. Even though the above schemes provide a formal explanation, they seem to be too demanding because of the many *ad hoc* ingredients that have to be introduced. Furthermore they neglect the observationally grounded hint that the stellar content of EGs is likely enhanced in α−elements with [α/Fe] ranging from 0.1 to 0.4 dex. We propose here a new scheme, in which the bulk dispersion of galaxies in the Hβ vs. [MgFe] plane is caused by a different mean degree of enhancement. In this model, neither large age ranges nor universal enrichment law for the old component are required and the observed distribution along Hβ is naturally recovered. Furthermore, later bursts of stellar activity are a rare event interesting only those galaxies with very high Hβ (roughly >2.5). Finally, simulations of the scatter in broad-band colors of EG's seem to confirm that the bulk stars have formed in the remote past, and that mergers and companion star formation in a recent past are not likely, unless the intensity of the secondary activity is very small.

(4) Tantalo R., Chiosi C., Munari U., Piovan L. & Sordo R. Absorption-line indices from high-resolution spectra.I. New response functions. (2004). MNRAS, submitted

Basing on the huge library of 1-A resolution spectra calculated by Munari et al. over a large range of logTeff, logG, [Fe/H] and both for solar and α-element abundance ratios [α/Fe], we present theoretical absorption-line indices on the Lick system. First we derive the so-called response functions (RFs) of Tripicco & Bell (1995) for a wide range of logTeff, logG, [Fe/H] and [α/Fe]=+0.4. The RFs are commonly used to correct indices with solar [α/Fe] ratios to indices with [α/Fe]>0. Not only the RFs vary with the type of star but also with the metallicity. Secondly, with the aid of this and the fitting functions (FFs) of Worthey et al., we derive the indices for single stellar populations and compare them with those obtained by previous authors, e.g. Tantalo & Chiosi (2004). The new RFs not only supersede the old ones by Tripicco & Bell (1995),
but also show that Hβ increases with the degree of enhancement in agreement with the results by Tantalo & Chiosi. This finding lends support to the suggestion made by Tantalo \& Chiosi that early-type galaxies of the Local Universe crowding the region of the Hβ versus [MgFe] plane comprised between 1<Hβ<1.7 and 3<[MgFe]<4.2 could have the same old age but different Hβ due to galaxy to galaxy variations in the mean degree of α-enhancement and metallicity. The classical interpretation is that they differ in the mean age and metallicity and that enhancement plays in practice no role and that the age difference is due to recent episodes of star formation. To explore this possibility we derive the age, metallicity and degree of enhancement for the galaxies of the Trager catalogue using the minimum-distance method, examine their position in suitable diagnostic planes and look for global correlations among the three parameters. Chief results of this analysis are (i) age and enhancement (together with metallicity) may concur to scatter the galaxies in the Hβ versus [MgFe]; (ii) at increasing age of the last episode of star formation, the mean metallicity decreases and the degree of enhancement increases as expected from current understanding of galactic chemical evolution and supernova contamination. Finally, we present preliminary indices on the
same system directly measured on the theoretical 1-A resolution spectra. The analysis is still preliminary because much narrower spacing in logTeff and logG than the one for the subset of the large library of Munari et al. we have adopted is indeed required. Work is in progress to include the desired spacing in the atmospheric parameters (logTeff, logG and [FeH] or [Z/Zo]).

Project 4: EFFECTS OF DUST ON THE SPECTRAL ENERGY DISTRIBUTION OF GALAXIES

(1) Piovan L., Tantalo R., & Chiosi C. ***Shells of dust around AGB stars: effects on the integrated spectrum of Single Stellar Populations*****. (2003). ASTRONOMY & ASTROPHYSICS. vol. 408, pp. 559-579**

In this paper we present models for Single Stellar Populations (SSPs) of intermediate and old ages where dust enshrouded Asymptotic Giant Branch (AGB) stars are introduced. As long known AGB stars are surrounded by dust-rich shells of matter caused by their own stellar wind, which absorb the radiation coming from the central object and re-emit it in the far infrared (IR). To this aim, particular care is devoted to follow the evolution of the AGB stars throughout the quiet and thermally pulsing regimes, to evaluate the effect of self contamination in the outermost layers by the third dredge-up mechanism, to follow the transition from oxygen-rich to carbon-rich objects (as appropriate to their initial mass and chemical composition), and finally to estimate the efficiency of mass-loss by stellar winds, all aspects that concur to the formation and properties of the dusty shells around. In addition to this, accurate physical models of the dusty shells are presented in which the re-processing of radiation from the central stars is calculated by solving the radiative transfer equations in presence of dust particles of different chemical composition. The resulting spectral energy distribution (SED) is examined to show how important features caused by silicates, like the 10 μm Si-O stretching mode feature and the 11 μm SiC feature, evolve with time. The SEDs are then convolved with the IRAS filters to obtain the flux in various pass-bands, i.e. 12, 25 and 60 μm, for individual AGB stars of different, mass, chemical composition, and age. The comparison is made by means of SSPs along which AGB stars of the same age but different initial masses are located. This allows us to explore the whole range of masses and ages spanned by AGB stars. The theoretical results are compared to the observational data for selected groups of stars. The same is made for the J,H,K, L pass-bands of the Johnson system. Finally, from the integrated SEDs of the SSPs, we derive the integrated Johnson J,H,K, L magnitudes and colors to be compared to infrared data for star clusters of the Magellanic Clouds. In general good agreement with the data is possible only if the effect of the circumstellar shells of dust are taken into account.

(2) Piovan L, Tantalo R., & Chiosi C. **Modelling galaxy spectra in presence of interstellar dust. I. The model of ISM and the library of dusty SSPs .*(2005) MNRAS, in press***

The advent of modern infrared astronomy has brought into evidence the role played by the interstellar dust in the subject of galaxy formation and evolution. Therefore, to fully exploit modern data, galactic spectro-photometric models must include the dusty component of the interstellar medium (ISM) and take into account all recent advancements in dust models. In this paper, the first of a series of two devoted to modelling the spectra of galaxies of different morphological type in presence of dust, we present our description of the dusty components, i.e. the diffuse ISM and the molecular clouds (MCs). Our galaxy model contains three interacting components: the diffuse ISM, made of gas and dust, the large complexes of MCs in which active star formation occurs and, finally, the populations of stars that are no longer embedded in the dusty environment of their parental MCs. In our dust model we take into account three components, i.e. graphite, silicates and polycyclic aromatic hydrocarbons (PAHs). We consider the two best recipes in literature for the size distribution of the dust grains, and adapt them to our aims. For the emission by ISM we also consider two models, namely the state-of-the art one of Li (2001) and a hybrid model derived by us modifying and combining the analysis of Guhathakurta et al (1989) for the graphite and silicates and of Puget et al (1985) for the PAHs. We cross-check the emission and extinction models of the ISM by calculating the extinction curves and the emission for the typical environments of the Milky Way (MW) and the Large and Small Magellanic Clouds (LMC and SMC) and by comparing the results with the observational data. The agreement between theory and observations is remarkably good. We apply our best dust model to calculate the spectral energy distribution (SED) of Single Stellar Populations (SSPs) of different age and chemical composition, which may be severely affectd by dust at least in two types of star: the young, massive stars while they are still embedded in their parental MCs and the intermediate- and low-mass AGB stars when they form their own dust shell around (see Piovan et al 2003 for more details about AGB stars). We derive the optical depth of the star forming MCs and apply the "Ray Tracing" method to solve the problem of radiative transfer across the MCs in which young stars are embedded. We also calculate extended libraries of SSPs specifically tailored for galactic population synthesis, the final goal of our study. The SEDs of young SSPs are then compared with observational data of star forming regions of local galaxies and show close agreement with observational data from the UV-optical regions to the mid and far infrared (MIR and FIR, respectively). Particular care is paid to model the contribution from PAHs, introducing different abundances of C in the population of very small carbonaceous grains (VSGs) and different ionization states in PAHs. These new SSPs should bring a net improvement when applied to model the total SED of galaxies of different morphological type, the subject of the second paper of the series.

(3) Piovan L.,Tantalo R., & Chiosi C. Modelling galaxy spectra in presence of interstellar dust. II. From the UV to the far infrared. (2005) MNRAS, in press

In this paper, we present spectro-photometric models for galaxies of different morphological type whose spectral energy distributions (SEDs) take into account the effect of dust in absorbing UV-optical light and re-emitting it in the infrared (IR). The models contains three main components: (i) the diffuse interstellar medium (ISM) composed of gas and dust whose emission and extinction properties have already been studied in detail by Piovan et al (2005}; (ii) the large complexes of molecular clouds (MCs) in which new stars are formed; and (iii) the stars of any age and chemical composition. The UV-optical light emitted by young stars can partially or even totally absorbed by the MCs in which they are immersed (Piovan et al. 2005). They are powerful IR-emitters. Similarly for the asymptotic giant branch (AGB) stars which are easily surrounded by the shells of dust they eject on their own (Piovan et al 2003). Finally the radiation emitted by all stars of any kind is absorbed and re-emitted in other wavelength intervals by the ISM. The galaxy models stand on a robust model of chemical evolution that assuming a suitable prescription for gas infall, initial mass function, star formation rate and stellar ejecta provides the total amounts of gas and stars present at any age together with their chemical history. The chemical models are taylored in such a way to match the gross properties of galaxies of different morphological type. In order to describe the interaction between stars and ISM in bulding up the total SED of a galaxy, one has to know the spatial distribution of gas and stars. This is made adopting a simple geometrical model for each type of galaxy. The total gas and star mass provided by the chemical model are distributed over the whole volume by means of suitable density profiles, one for each component. The density profiles depend on the galaxy type (spheroidal, disk and disk plus bulge), The galaxy is then split in suitable volume elements to each of which the appropriate amounts of stars, MCs and ISM are assigned. Each elemental volume bin is at the same time source of radiation from the stars inside and absorber and emitter of radiation from and to all other volume bins and the ISM in between. They are the elemental seeds to calculate the total SED. Using the results for the properties of the ISM obtained by Piovan et al (2005) and the SSPs calculated by Piovan et al (2003, 2005} we derive the SEDs of galaxies of different morphological type. The analysis proceeds in steps. First the technical details of the method are described and the basic relations driving the interaction between the physical components of the galaxy are presented. Second, the main parameters are examined and their effects on the SED of three prototype galaxies (a disk, an elliptical and a star-burster) are highlighted. The final part of the paper is devoted to assess the ability of our galaxy models in reproducing the SEDs of a few real galaxies of the Local Universe.

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