Concluding Remarks
and
Hints for Future Work

Cesare Chiosi

Main Topics

- I – Stellar nucleosynthesis and populations
- II – Milky Way and Local Group of galaxies
- III – Ellipticals and high-redshift Universe

Stellar Nucleosynthesis & Populations

Andre Maeder *Effects of stellar physics on the chemical yields (SI)*

Marco Limongi *Chemical yields of rotating and non rotating massive stars at various metallicities (SI)*

Georges Meynet *Physics of spin-stars and some consequences for the chemical evolution of galaxies (SI)*

Friedel Thielemann *The hunt for the site of the r-process: constraints from nuclear physics, low metallicity stars, and attainable conditions in astrophysical stellar models (SI)*

Stellar nucleosynthesis & populations

Ken'ichi Nomoto	*Progenitors of Type Ia Supernovae (SI)*
Laura Greggio	*The evolution of the rate of type Ia supernovae (SI)*
Massimo Della Valle	*Supernovae shed light on Gamma-ray Bursts (SI)*
John Danziger	*Dust in Supernovae (SI)*

DISCUSSION SESSION I

- I – Stellar nucleosynthesis and populations
- II – Milky Way and Local Group of galaxies
- III – Ellipticals and high-redshift Universe

- Stellar nucleosynthesis both in static and explosive modes is the preliminary step towards undestanding chemical abundances and their evolution in galaxies and the universe as a whole.

- The issue is very difficult and complex at the same time.ITo mention a few, it depends on many factors: the cross sections of the thosands of possible reactions, structure of the stars (uncertainties due to mixing), initial chemical composition, stellar winds, stellar rotaion and its side effects, etc …

- In this context we had a few important contributions: the chemical ejecta of rotating and non rotating massive stars of different mass and metallicities; the abundances of many elements are followed from the MS to the SN explosion stage and their production factors are derived (Limongi).

- Closely related to this are the studies of the effects of stellar physics, i.e. rotation, mass loss and mixing (Maeder) and of the spinstars, (high initial rotational velocity) and how rotation alters their evolution with predictions for the surface abundances and how the spectro-photometric properties of CC-SNae progenitors are affected by this (Meynet).

- All this constitutes a body of data to be implemented in the calculations of stellar ejecta and the yields per stellar generation. How to do this without loosing the important details that perhaps fiind observational counterparts?

- We want to keep the richness of the theoretical results. Avaraging them out may not be wise. I think we must change approach and address to the most powerfultool to our disposal , ie. adopt the language and methods of Statistical Mechanics and explore the full space of parametres or possible configurations. Similar approach has been proposed to deal with CMDS containing billions of stars. Why not nucleosynthetic data and associated chemical modeling.

- Closely related to this subject are the two papers on the s -and r-processes (Trippella, Thieleman-Meynet). In the s-process nucleosyhthesis, the problem of the 13C pocket is still with us , even if a new interesting idea based on MHD has been suggested and promises to be succesful. r-process nucleosynthesis is a cumbersome issue still looking for a firm site of occurrence (maybe more than one) and full physical understanding. Important news: CC-Sne explode in 2D and 3D simulations.

- The situation for SN-Ia has been reviewed by Nomoto: various possible channels at sub-Chandra and Chandra limits. Is the issue settked down? Naive question: Is our understanding of the basic physics of WDs , the old ones in particular, fully statisfactory?

- Theoretical modelling of chemical enrichment needs the SN rates, the SNIa in particular because of its time delay. Basing on the DD scenario, Greggio has recently revised the SNIa taking into account the shrinking of the separation of the binary system during the evolution.

- In relation to SNae Danziger has reviewd the observational situation for the amount of dust in the SN1987A ejecta. Owing to the important role of dust also in chemical modeling the issue is very important. Total amount of dust about 0.4-0.7 Mo, estimated amount of CO (0.01 Mo).

- The subject of SNae is closed by Della Valle who argues on the role played by SN in shedding light on CRBs. The conclusions is that GRBs are rare compared to SNae, and we are left with the home work “what causes a star to become a GRB progenitor instead of a stable SN. To facilitate the task various plausible explanations are put foward.

II – Milky Way and Local Group Galaxies

Monica Tosi — Chemical evolution modelling: the role of star formation histories and gas flows

Jordi Isern — What white dwarfs are telling us about the structure and evolution of the Galaxy

Raffaele Gratton — Globular clusters role in formation of the halo (SII)

Francesca D'Antona — What lithium and helium patterns tell us about the formation of Globular Clusters (SII)

Martin Asplund — The first stars in the Galactic bulge (SII)

Thomas Bensby — Chemical evolution of the Galactic bulge as traced by microlensed dwarfs (SII)

II – Milky Way and Local Group Galaxies

Michael Rich — Composition of Giants in the Galactic Bulge: Problems and Prospects (SII)

Manuela Zoccali — Abundance and kinematics in the Galactic bulge (SII)

David Yong — Element abundance ratios in stars of the outer Galactic disk (SII)

Mathias Schultheis — The APOGEE survey and its first results (SII)

Sofia Randich — The Gaia-ESO Survey (SII)

Daniela Carollo — Carbon-Enhanced Metal-Poor Stars from SDSS and LAMOST as Probes of the Early Chemistry of the Galaxy (SII)

II – Milky Way and Local Group Galaxies

Patrick Francois Lithium abundance in the metal-poor open cluster NGC 2243 (SII)

Laura Magrini Clues on the formation and evolution of the Galactic disk with open clusters (SII)

Cristina Chiappini Chemodynamical model for the Milky Way: a new approach (SII)

Gabriele Cescutti Very heavy elements in the early Universe (SII)

Emanuele Spitoni Effects of radial flows of gas and galactic fountains on the chemical evolution of galaxies (SII)

Nikos Prantzos The role of radial migration in the chemical evolution of galactic disks (SII)

II – Milky Way and Local Group Galaxies

Monica Midori Marcon Uchida   Chemical Evolution of Stellar Systems in the Local Group of Galaxies (SII)

Brad Gibson   Chemodynamical Simulations of Disk Galaxies (SII)

Moelia Jimenez   Feedback and chemical enrichment due to supernovae Type Ia in cosmological hydrodynamical simulations. The inclusion of analytical delay time distributions (SII)

Vanessa Hill   Stellar chemistries in the nearby dwarf galaxies (SII)

Andreas Koch   Chemical evolution on smallest scales - hints from observations of dwarf galaxies (SII)

Matthew Shetrone   Carbon in dwarf Sph galaxies (SII)

II – Milky Way and Local Group Galaxies

Andy McWilliam The Sagittarius dwarf galaxy (SII)

Gustavo Amaral Lanfranchi Chemical Evolution Models for Local Dwarf Spheroidal Galaxies (SII)

Simone Recchi The effect of geometry on the development of galactic winds in dwarf galaxies (SII)

Discussion, Session II, Leader: Donatella Romano

Main Topics

- I – Stellar nucleosynthesis and populations
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- The topic is introduced by Tosi who highlights the role of infall together with winds in solving a number of well known problems, discusses the variation of the SFH with galaxy type and the CMDs of field star populations and the SFR-Z-age relationships in nearby galaxies. .

- *A point to clarify here is that infall is best meant as the combined effect of SFR and mass accretion time scale and that any open scheme is more efficient (faster) in enriching the ISM, counterintuitive by true.*

- Looking for the past structure and evolution of the MW, WDs are best tracers owing to apparently simple internal structure (Isern). The halo GCs that turn out to be more complex systems that thought ever before,. Intersting enough GCs and dSPhs maybe obey the same MMR (Gratton). What is the origin of the Li dip and anticorrelations between important elements . Do GCs form in two steps ? (D'Antona).

- The Galactic Bulge is fascinating on its own. Is the Bulge the site to look for the first stars (very old and very metyal poor)? Asplund sets the question and shows details about the Skymapper project, Along a similar line, the microlensing technique is applied to dwarfs and subgiants towards the Bulge, revealing examples of extremely metal-rich and also younger stars. Are these stars in the Bulge ? (Bensby). Rich presents data on composition and kinematics of Bulge stars.

- Finally the stellar content and shape of the Bulge are addressed by Zoccali. Chemical abundances, kinematics are analyzed to suggest that the Bulge could have two Components: mwtal-poor one formed on a short time scale (0.5 Gyr), a metal-rich one formed on a longer time scale (3 Gyr).

- Perhaps 3 peaks in AMR. The Bulge seems to have a X'shape structure (a sort of double bar), perhaps radial gradients in metallicity. Most stars are old and metal rich. However a younger population seems to be there. See Ng etal (1998) for the same conclusions. It is a pleasure to see that after all they were not wrong!

- Moving now to the Galactic Disk, Yong presents results on the metallicity gradients across the disk derived from OCs. Two slopes are suggested with turning point at about 13 kpc (but different hint from Cepheids).

- Schultheis reports on APOGEE campaign showing some preliminary results, whereas Randich reports on the GAIA-ESO surveys and its core science (dynamical evolution of clusters, stellr paremeters (ages, masses, galaxy phase space, inner radial z-gradient and transition from thin to thick disk, and more.

- CEMP stars are an intriguing subject (Carollo D) whose origing and role in the scene of Galactic Halo is still a matter of speculation (most likely they are the low mass companion of a binary system whose primary has already evolved through the AGB phase). Perhaps some connection with the double structure of the halo.

- Francois brings us back to Li discussing the case dwarf stras of the metal poor OC NGC2243. Estimates of the mass of the star at the blue edge of the dip. Putting together other data this mass seems to dececrease with Z. Why? Compare with Li in 47 Tuc apparently no Li-evolution during the past 8 Gyr. Why? Using OCs of the GAIA Eso survey, Magrini sets clues on the formation and evolution of the Galactic Disk, in particular the age DF and the metallicity gradient.

- Chemistry! Chemistry! The symphony is started by Chiappini with her chemo-dynamical model for the MW. Aim is to investigate how various key relations (e.g. the metallicity distribution) are affect by dynamics, i.e. migration of stars from one region to another of the disk. Is all this invalidating the classical assumption that the G-dwarf MDF mirrors the time scale of mass accumulation? We shall see.

- The same question has been addressed by Prantzos. With the aid of N-body simulations he check the consistency with seminalytical models. In both cases I have some concerns about the mutual consistency of the different approaches (numerical vs semi-analytical).

- Marcon-Uchida investigates the chemical evolution of galaxies in the LG using the standard technique. Why in the case of M31 the IMF is taken to be flatter than Salpeter? Furthermore, in the case of LMC, why a single recent burst? In literature, studies of SFR from field starCMDs have suggeted that several episodes of SF have occurred, perhaps triggered by close encounters of the LMC (+SMC) and the MW . Mutual consistency should be considered.

- Spitoni reports on the effect of radial flows and galactic fountans . These latter simply delay pollution by SNII. The former yields the inversion in the metallicity gradient at about 5 kpc (already in Portinari & Chiosi 2000).

- Cescutti rises the question of the very heavy elements in the early universe focusing on the spread in the [X/Fe} vs [Fe/H] planes for elements like Ba, Sr. Plausible, convincing explanations are given.

- Kobayashi starting from cosmological simulations build up a disk like galaxy and intriducing chemical enrichment looks at abundances and abundance gradients in different regions and directions. The bottom line is that inhomogeneous chemical evolution is the rule and on the long run will replace the predictions from classical semianalytical models. Side considerations are for AGNs, the BH mass vs total mass relationship and the [El/Fe]vs Mass-sigma relation,

- Jimenez deals with the importance of SNIa feed back and presents results for the SFR vs age relation at varying the prescription for SNIa.

- Hill and Koch address very similar questions: why alpha enhacements in stars of dwarf galaxies are lower than those of the MW? Problem of the Knee in the alpha/Fe vs Fe/H plane: Sextans and Carina no knee at all only dispersion. Is this due to IMF? Hill also discusses problems related to heavy elements from the s- and r-channels. Koch looking at Ca/Fe, Mg/Fe Co/Fe and Ba comes to suggest that there should be incomplete sampling of the upper IMF, and failure to simulaneously fit with modesl alfa elements and n-capure elements..

- The point is strengthned by McWilliams who basing on 3 RGBs in Sagittarius and the lack of simulatneous fit of O/Fe and Eu/Fe suggest sthat two different sources are required and that the IMF in dwarf galaxies should be top-light. I personally was much impressed by this result because about 15 years ago and basing on different arguments we claimed that the IMF should get more and more skewed toward massive stars passing from dwarf to massive galaxies (Chiosi et al 1998, A&A 339, 355). Too premature!

- Shetrone addresses the question why Carbon is so difficult to measure. Lanfranchi presents chemical models for dSphs in particular for heavy s- and r-process elements: case of (Eu, La, Yr, Ba) in Formax. Adjust the model parameters according to needs (larger yields). Finally Recchi shows intersting experiments on galactic winds from dwarfs, in particular the effect of geometry thickness of disks on the onset of galactic winds and refueling of the void region with gas flowing in from neighbouring regions (implications for metal enrichmnet).

- There are two considerations coming to my mind.

- First of all we are facing a wealthy of data of unprecedented quality. Large scatters are presents in the abundances and abundance ratio that can hardly reduced to ere observational errors, It seems as if there are either many sources (difficult to pin dow) concurring to ….. To cure the problem one invokes changes in the leading parameters (sfr, imf, infall, etc..). However we sholud change attitude and ask oureselves if an intrinsc scatter may be present. In such a case the classical formulation of the chemical models may not be correct. Perhaps a stochastic description of the whole problem is required, We should change mind and develop new theoretical tools.

- Concerning dwarf galaxies, the ones we have easy access are those of the LG, But most of them are satellites of the MW and M31. How much dynamical interactions may concur to shape their morphology and properties is not known . This should be urgently considered.

III – Ellipticals and High-Redshift Universe

Luca Ciotti *AGN feedback and the evolution of elliptical galaxies)*

Simon Lilly *Chemical evolution in gas-regulated galaxies, and the links with the cosmic evolution of galaxies and haloes*

Carlo Morossi *Lick/SDSS library v2.0: a new tool to compute model of stellar populations with variable Alpha element abundance ratios*

Cesare Chiosi *The chemical evolution of elliptical galaxies*

Roberto Maiolino *Metals and dust evolution throughout the cosmic epochs*

III – Ellipticals and High-Redshift Universe

Stefano Cristiani *Chemical Evolution of the Intergalactic Medium (SIII)*

Paolo Tozzi *The evolution of the Fe abundance in the Intra Cluster Medium (SIII)*

Alvio Renzini *Constraints on galaxy evolution from the chemistry of clusters of galaxies (SIII)*

Sandro D'Odorico *Chemical abundances at high z from observations of lensed galaxies (SIII)*

III – Ellipticals and High-Redshift Universe

Raul Jimenez *Enriching the universe at z>10: how the first galaxies formed (SIII)*

Marcella Carollo *Environmental Triggers of Galaxy Evolution (SIII)*

Discussion, Session III Leader: Francesco Calura

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- AGN feedback on the evolution of EGs is discussed by Ciotti: comparing the available gas mass shed by stars to the mass of BH, this latter is much smaller than expected; are BHs able to stop mass acrretion? Simulations of mechanical and raditiave feedback show that initally FB increases Star Formation whereas later on galactic winds clear the gas content. 2D simulations show little impact on galaxy evolution.

- Lilly presents results on the gas-regulation of galaxies: the evolution of the cosmic sSFR, the metallicity-mass-SFR relation and the stellar content of haloes. A sophisticared analytical model is presented to understand the key process regulating galaxy formation. From what aI could gather there seem to be a general agreement with the results from the monolithic scheme in particular for what comcern their sSFR and the dependence of this with galaxy mass.

- Morossi describes a new library of spectral indices at high resolution that auseful to population synnthesis.

- Maiolino deals wiith the evolution of metals and dust in galaxies at different epocs. The chemical content and evolution of the ICM.

- Finally the chemical evolution of the IGM and ICM is the subject of the contributions by Cristiani, Tozzi and Renzini. .

- The latter in particular revisits an old problem related to the metal content in the IGM, and the metals stored in galaxies which apparently lead to contradictory results. No conclusion is drawn even though the suspicion goes to the extimate of the cluster mass made in two different ways. Stay tuned .
- D'Odorico reviews the discovery of lensed galaxies, summarizes the physical interpretaion of arcs and the advantages given by these to observe the high z universe, talks about chemical abundances at high z observations of lensed galaxies: verify mass metallicity relation and metals already close to solar.

- Jimenez R deals with the universe at z>10 and the formation of galaxies. Experiments with atomic and molecular cooling in DM halos. Role of mergers at setting the conditions of galaxy formation, gas cools faster than DM, gas rotates faster than DM, misalignement of gas and DM spins, blobs and donuts in different regions (cosmic knots and filaments), Include molecules (H2 and HD) .
- Carollo M addresses environment conditions triggering galaxy evolution. Mass ((galxy) and density (envir) dependence of quenching from blue to red galaxies. Minor mergers not sufficient to explain variations with z. Evolution of size with z. At all masses most growth in Q populatiom observed at large sizes-. Compact Q EG redder, stable stellar population do not evolve in size, larger Q bluer i.e. younger, Increase of size with z caused by accretion of larger Q EGs ....

Hints for the coming years

Flashes on

- ICM in NB-TSPH simulation
- The important role of dust (creation, destruction, reprocessing of radiation, spectro-photometry for local and far away galaxies (redshift)

5. ISM with ROBO and MaNN

- Thermodynamic and chemical treatment of the ISM in NB-TSPH simulations is difficult to model.
- Grassi et al (2011a,b) proposed a method to include the ISM in NB-TSPH simulations and to get the cooling rate as a side self-consistent product.

The ISM: ROBO and MANN Founding Hypotheses

- Ideal ISM element of unit volume.
- Gas and dust in arbitrary initial proportions.
- Initial physical conditions specified by a set of parameters (e.g. n, T, n_i etc.).
- ISM element mechanically isolated from the surrounding environment, i.e. it does not expand or contract under the action of large scale forces.
- However, it can be interested by the passage of shock waves generated by physical phenomena (e.g. SN explosions taking place elsewhere).

Founding Hypotheses (2)

- History leading the ISM element to that particular state not relevant here.
- ISM element does lose nor acquire material, i.e. mass conservation,
- Is immersed in a bath of UV radiation generated by internal or external nearby sources. It is not necessary to know the whole SED,
- Is immersed in the field of cosmic radiation $T_{CR}(z)$,
- Can generate its own radiation field.

Founding Hypotheses (3)

- Has its own thermodynamical state (temperature, density, pressure etc. all governed by the EOS.
- Given these premises, the ISM element evolves from state A to state B over the time scale ΔT, changing the internal physical parameters and the internal chemical composition by the effect of a large variety of chemical reactions, and heating and cooling processes.
- Integration Time Interval Δt: is :

a) long enough to secure the secular evolution of the ISM.

b) short enough to secure that the physical properties of the ISM are nearly independent of the large scale evolution of the host galaxy.

Vector Field of Physical Properties

- ROBO associates to **any** **initial state** (a point in the multidimensional space of physical parameters) **a** **final state** (another point in the same space)

A → ROBO → B

initial **final**

Elemental Species, Molecular Compounds, and Chemical Reactions

ROBO follows the evolution of 28 elemental species and molecular compounds as determined by a network of 76 chemical reactions

Table 1. Correspondence between elemental species or free particles and the indices of the differential equations governing the reaction network.

Ele.s	H	H^+	H^-	H_2	H_2^+		
Ind.s	1	2	3	4	5		
Ele.s	D	D^+	D^-	D_2	HD	HD^+	
Ind.s	6	7	8	9	10	11	
Ele.s	He	He^+	He^{++}				
Ind.s	12	13	14				
Ele.s	C	C^+	CH	CH_2	CH_2^+	CH_3^+	CO
Ind.s	15	16	17	18	19	20	21
Ele.s	O	O^+					
Ind.s	22	23					
Ele.s	Si	Si^+	Fe	Fe^+	e^-		
Ind.s	24	25	26	27	28		

- collisional ionization ($A + e^- \rightarrow A^+ + 2e^-$),
- photo-recombination ($A^+ + e^- \rightarrow A + \gamma$),
- dissociative recombination ($A_2^+ + e^- \rightarrow 2A$),
- charge transfer ($A^+ + B \rightarrow A + B^+$),
- radiative attachment ($A + e^- \rightarrow A^- + \gamma$),
- dissociative attachment ($A + B^- \rightarrow AB + e^-$),
- collisional detachment ($A^- + e^- \rightarrow A + 2e^-$),
- mutual neutralization ($A^+ + B^- \rightarrow A + B$),
- isotopic exchange ($A_2^+ + B \rightarrow AB^+ + A$)
- dissociations by cosmic rays ($AB + CR \rightarrow A + B$),
- neutral-neutral ($AB + AB \rightarrow A_2 + B_2$),
- ion-neutral ($AB^+ + AB \rightarrow AB_2^+ + A$),
- collider ($AB + C \rightarrow A + B + C$),
- ionizations by field photons ($A + \gamma \rightarrow A^+ + e^-$)

Inserting ROBO into EvoL via MaNN

- We want now to include our treatment of the ISM into NB-TSPH simulations of cosmological backgrounds and/or galaxy formation and evolution.

- The easiest way and in practice at no computational cost is the ARTIFICIAL NEURAL NETWORKS (ANN). The algorithm **predicts an output state from an initial input state**.

Artificial Neural Networks (1)

- Three groups of neurons: input, hidden (auxiliary), and output.
- Each neurons performs a simple task: it becomes active if the input signal is stronger than a threshold. If active it emits a signal to the other neurons. Each unit acts as a filter increasing or decresaing the signal.
- The whole process is described by

$$n_i = f(x)\left(\sum_j w_{ij} n_j - \theta_i\right)$$

$$f(x) = \frac{1}{1 + e^{-\beta x}}$$

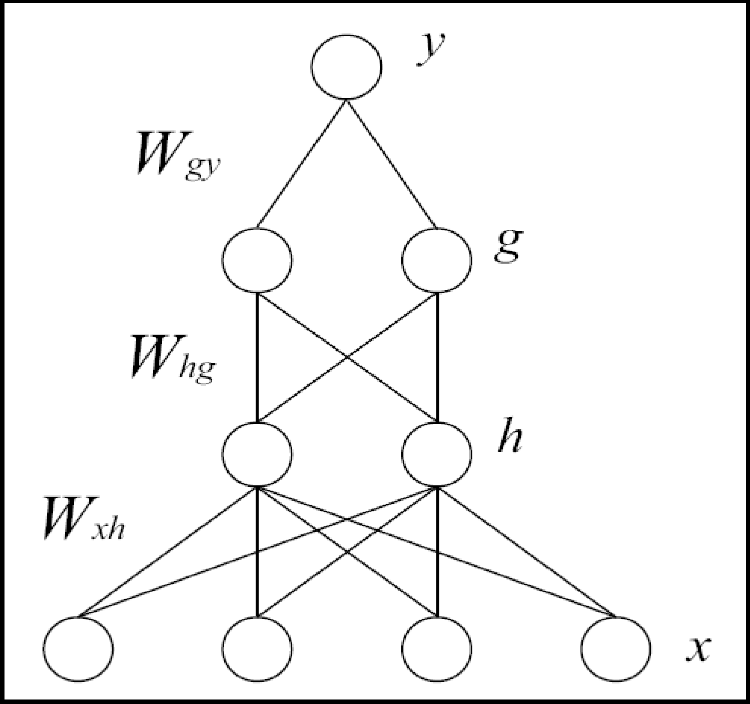
- n_i is the neuron value, *f(x)* is the activation function, w_{ij} is the weight between the *i* and *j* neuron, z_i is the threshold, *x* is the signal. Other expressions can be used for *f(x)*.

Artificial Neural Networks (2)

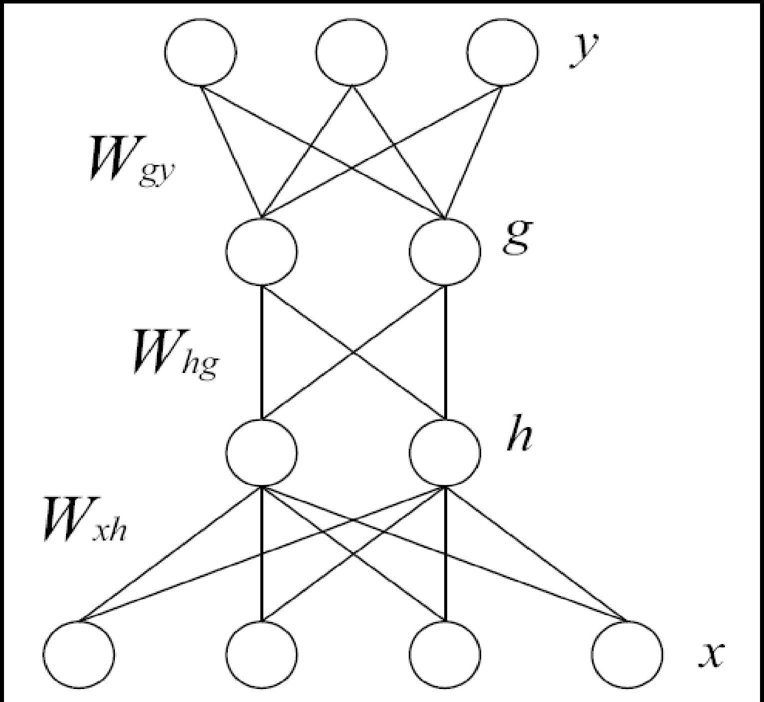
- Procedure is repeated until a certain precison is reached.
- Different architectures for the network are possible, e.g. the single output or multi-outputs and several layers of hidden neurons.
- The input and output data must be normalized
- Below two examples of architectures we have adopted

MaNN Architecture

Single – Output MaNNs



Multiple – Ouputs MaNNs



To conclude …….

- ROBO and MaNN are two robust descriptions of the thermodynamic evolution of the ISM and also two flexible tools to iimplement these important physical properties in NB-TSPH simulations.

A Vector Field plus ANN have solved the problem !

14. Modeling the galaxy ISM in presence of Dust: Chemistry & Photometry

- Thermodynamic and chemical treatment of the ISM in NB-TSPH simulations is difficult to model.

- Grassi et al (2011a,b) proposed a method to include the ISM in NB-TSPH simulations and to get the chemistry (and the cooling rate as a side self-consistent product). ROBO & MaNN.

- The same procedure can be used to include and the Dust (not yet completed). In the following, we present results from classical chemical models for gas and dust coupled together (Cassarà et al. 2013a, b; Piovan et al. 2013a,b,c).

State-of-the-Art

Modern infrared instrumentation (e.g. IRAS, ISO, CIRB, COBE) has revealed the existence of thousand of galaxies emitting most of their light in the IR whose origin is attributed to emission by DUST

Precious information on SFH of Galaxies and Universe is hidden in the UV-optical and IR ranges of the SED

DUST can be associated to stars and/or dispersed in the ISM.

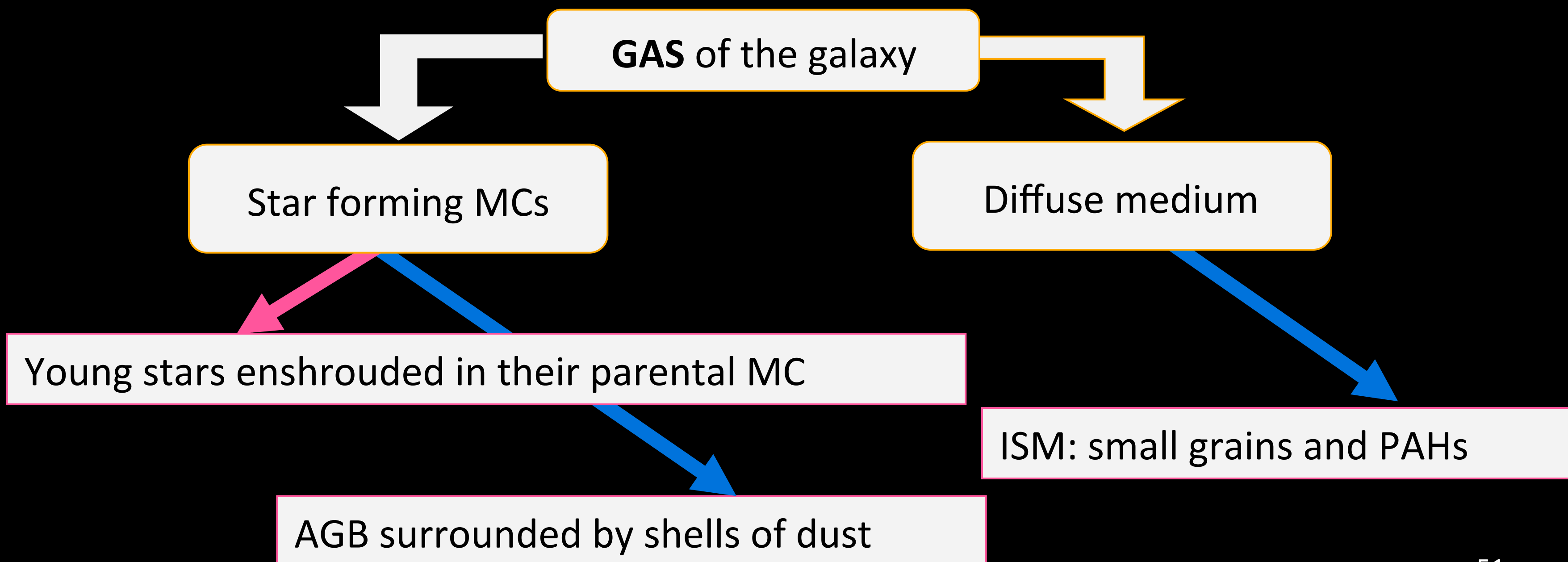
- Young stars are embedded in the parental molecular clouds (MCs),.
- AGB stars may form an outer dust-rich shell
- Thanks to continuous emission of metal-rich material by stellar wind the ISM acquires a dust-rich component

Therefore the effect of dust can not be neglected ⇨ a fraction of the UV-optical radiation is shifted to the IR region

State-of-the-Art

Classical population synthesis models do not take into account the effect of dust on the galaxy SED (Bressan et al. 1994, Tantalo et al. 1996, 1998).

The presence of the ISM and its effect on SEDs of spctro-photometric models has been taken into account for the first time by Silva (1998) followed by Silva et al. (1998,1999 GRASIL), Devriendt et al (1999 STARDUST) and Takagi et al. (2003), Piovan et al (2006a, b), Cassarà et al. (2013a,b), Piovan et al. (2013).



The Interstellar Medium

ISM

Gaseous part:
atomic gas, molecular gas, ionized gas

Solid part:
particles (grains) of many shapes and Dimensions (Interstellar Dust)

Dust: (i) attenuates radiation from far objects; (ii) absorbs radiation as function of λ; (iii) scatters the light; (iv) polarizes the stellar light; (v) shapes the spectra of galaxies … etc.

Extinction & Emission

Extinction curves shows a bump in the UV at 2175Å ⇐ Carbonaceous particles

Absorption features at 9.7 μm and 18 μm ⇐ Silicates : *Si-O* & *O-Si-O*

Graphite

Silicates

Emission peak in far-IR (COBE/FIRAS) ⇐ VSGs: carbonaceous material

Emission lines at: 3.3, 6.2, 7.7, 8.6 and 11.3 μm ⇐ PAHs

Modeling galaxy spectra

large complexes of MCs
in which active SF occurs

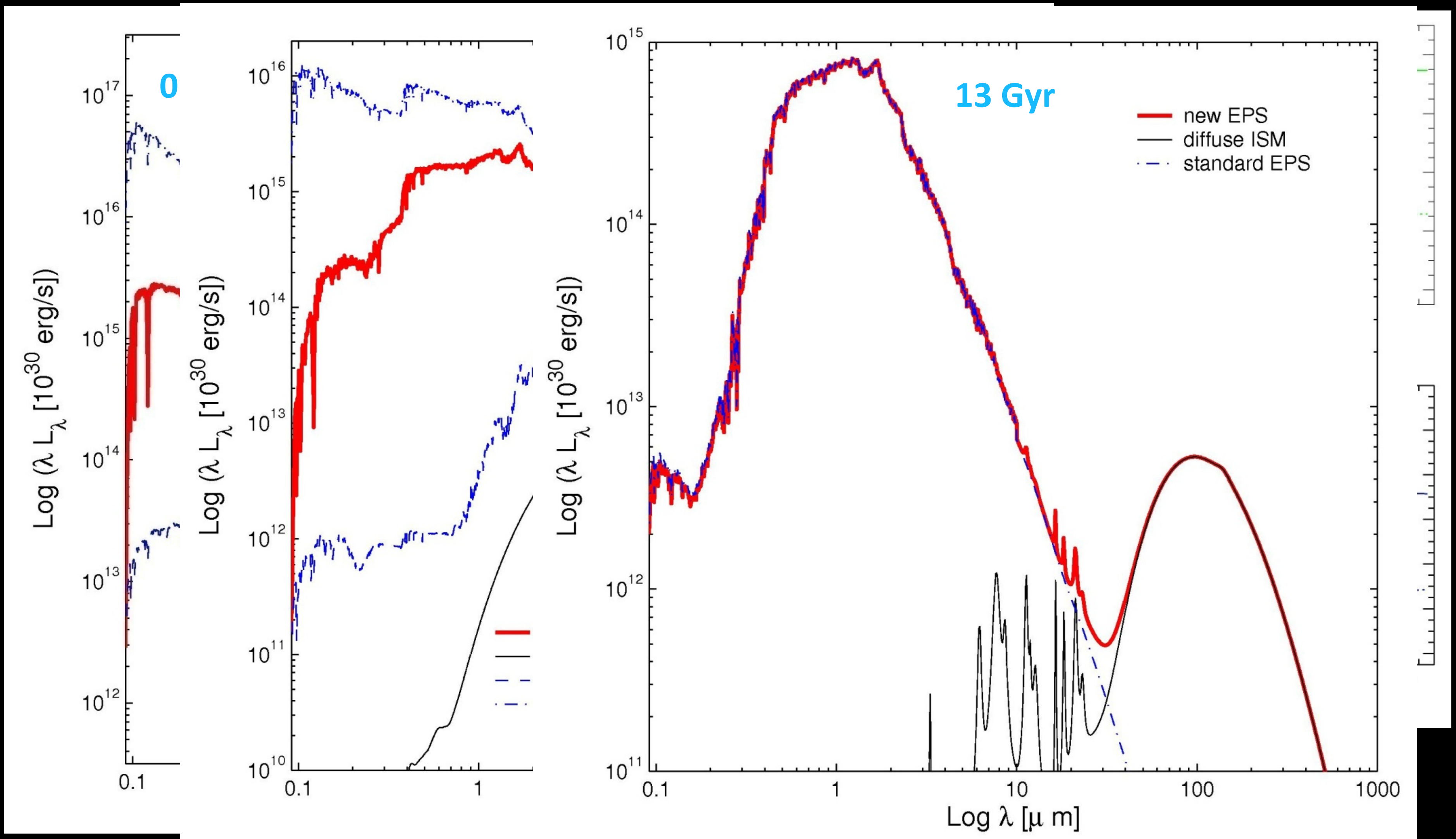
diffuse ISM (dust and
atomic and molecular gas)

Manifold of stellar populations of
different ages & metallicities

Need to assume / define ……

- The model (chemical, geometrical structural, etc..)
- SFR & IMF
- Elemental volume grids in geometry
- The mass spectrum of MCs
- Thermodynamical evolution of ISM, and dust properties
- Model for creation/ destruction of dust coupled to gas. Otherwise fraction of dust with respect to gas (function of age, metallicity….)

SEDs for Early-Type Galaxies



Spectra of E, Sbc and Disk at the age of 13.09 Gyr

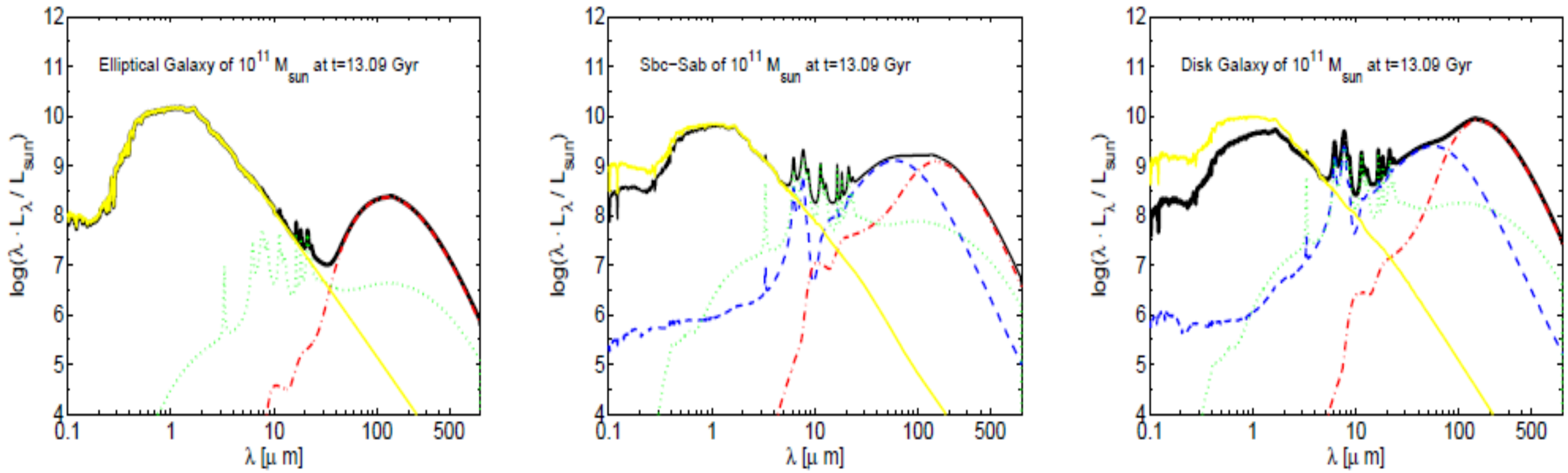
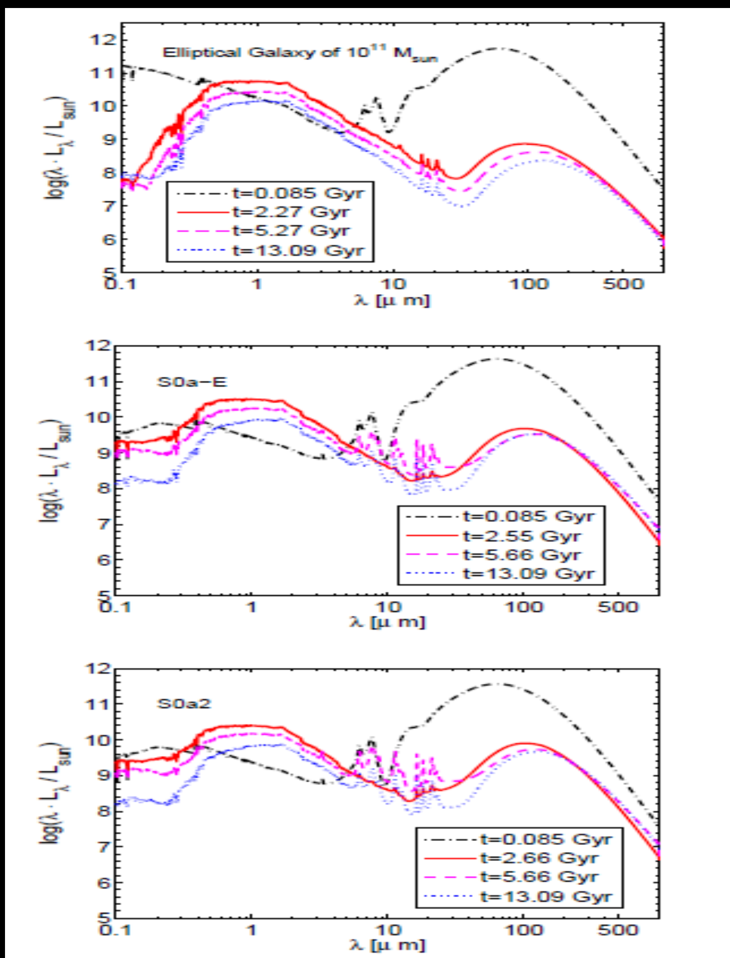
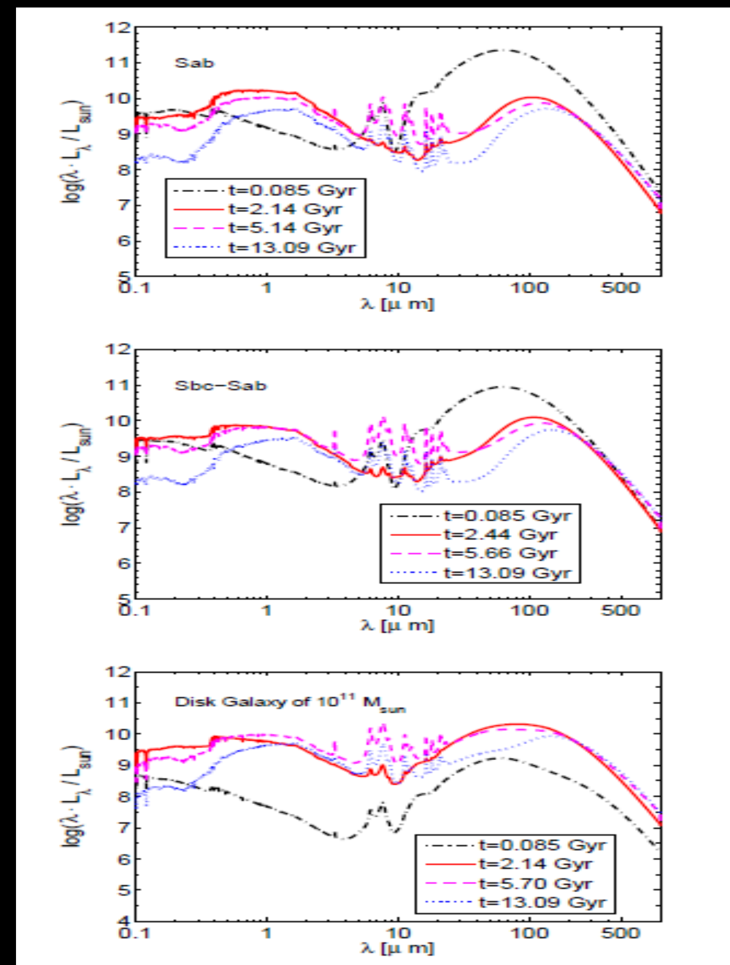


Figure 3. Left Panel: SED of the model *elliptical galaxy* of $M = 10^{11} M_\odot$ (black continuous line). We represent also the emission of both graphite and silicate grains (red dot-dashed line), the emission of PAHs (green dotted line), and the SED where only the extinction effect of the MCs is included (yellow continuous line). Middle Panel: The same as in the left panel, but for a *Sbc-Sab galaxy* of $M_{tot} = 10^{11} M_\odot$. The meaning of the lines is the same as in left panel. Right Panel: The same as the left and middle panels, but for a pure disk galaxy of $M = 10^{11} M_\odot$. The meaning of the lines is always the same as before.

Different Galaxies at different ages





…and as function of redshift

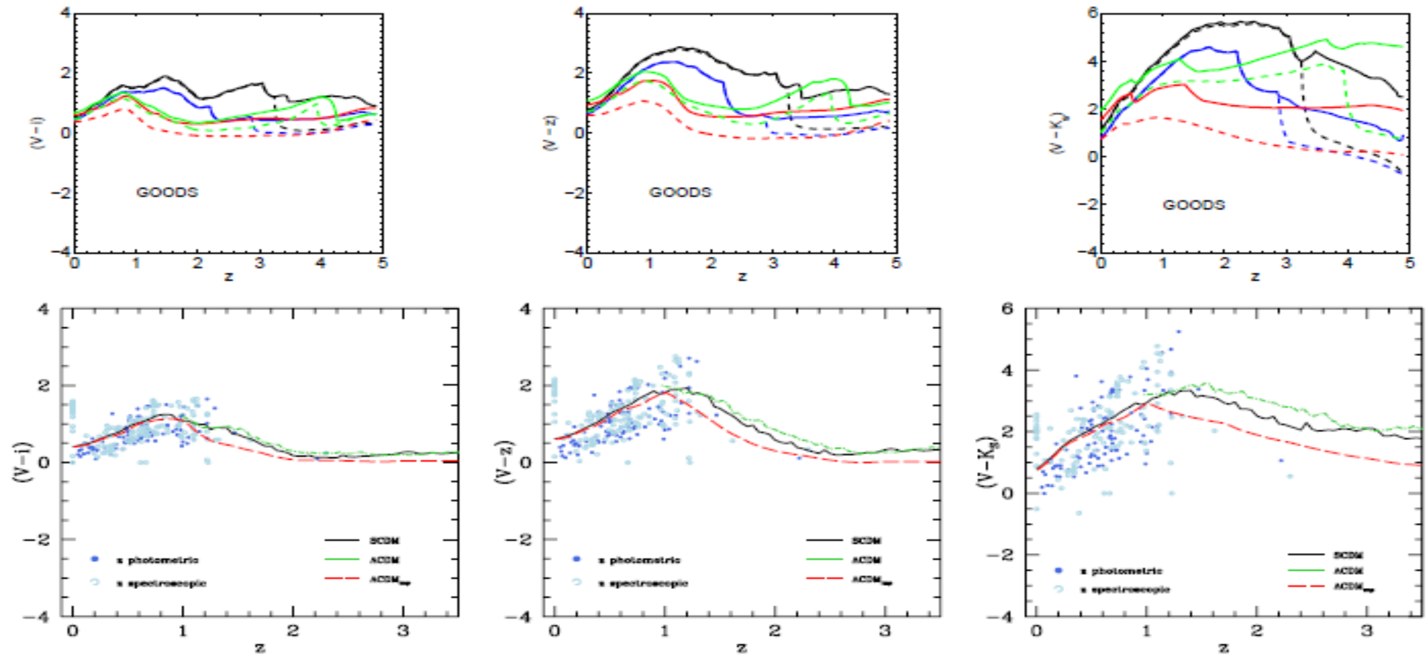


Figure 11. Left Panels: Cosmological evolution with the redshift for the color $V(F606W) - i(FTT5W)$ of the survey GOODS (bands ACS-HST). Lower panel: the sample of galaxies represented has been selected in Tantalo et al. (2010) and it is built with Early-Type Galaxies with photometric estimate of the redshift (blue filled circles) or spectroscopic estimate (light blue empty circles). The evolution of the color $V(F606W) - i(FTT5W)$ is shown for three EPS models from n-body simulations in different cosmological scenarios. See Tantalo et al. (2010) for more details. Upper panel: the evolution of the color $V(F606W) - i(FTT5W)$ for three models presented in this thesis work or ad-hoc calculated for this redshift evolution, namely: (1) two elliptical galaxies with masses $10^{10} M_{\odot}$ and $10^{12} M_{\odot}$ and with the same choice of the input parameters as in Sect. 6.4 (black and blue lines); (2) an intermediate type model Sab of $10^{11} M_{\odot}$ (green line) and (3) a disk galaxy (Sd) of $10^{11} M_{\odot}$ (red line). In all the cases we show the evolution of the color taking into account our dusty EPS (continuous lines) and classical EPS without dust (dotted lines). **Middle Panels**: The same as in the left panels but for the colour $V(F606W) - z(F850LP)$ of the survey GOODS (bands ACS-HST). **Right Panels**: The same as in the previous panels but for the color $V(F606W) - K_S$ of the survey GOODS (V band from ACS-HST and K_S from VLT-ISAAC).

References for ISM and Galaxy Spectra in presence of Dust

- Piovan et al. (2006a, MNRAS, 366, 923)
- Piovan et al. (2006b, MNRAS, 370, 245)
- Cassarà (2012, PhD Thesis, University of Padova, Italy)
- Cassarà et al. (2013a, MNRAS, in press)
- Cassarà et al. (2013b, in preparation)
- Piovan et al. (2013 a, A&A, in press, see arXiv1107.4541)
- Piovan et al. (2013 b, A&A, in press, see arXiv1107.4561)
- Piovan et al. (2013 c, A&A, in press, see arXiv1107.4567)

see also

- Grassi et al. (2011, A&A, 533, 123)
- Grassi et al. (2011, submitted to A&A, pending, arXiv1103.0509)

Conclusions for galaxy models with dust

- Successful modeling of the dust creation / destruction processes in the context of the chemical enrichment history of a galaxy
- Satisfactory SEDs of galaxies with different morphological type, mass and age.
- Satisfactory colors as a function of the redshift
- Much more work is needed !