Iterative technique to interpret OASIS data from spiral galaxies

Authors: Mercedes Mollá, Simon Cantin, Carmelle Robert, Anne Pellerin

Abstract

- We present our iteractive method to describe simultaneously the different stellar components which are apparent in the emission and absorption lines seen in the spectra obtained by OASIS.

- We show the technique and the results obtained for the central region of the barred spiral galaxy NGC 4900.

- Differences in the interpretation and results with and without this iterative technique are evident, what could imply erroneous conclusions when it is not used.

- In particular, the age of the young stellar population would have been overestimated while the age of the old one would have been underestimated.

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The work

- We have observed the centers of a sample of barred galaxies to study their stellar populations.
- Using the integral field spectrometer OASIS and analyzing these data by means of evolutionary synthesis models, LavalSB for young (<10 Myrs) stellar populations and the one from Gónzalez-Delgado et al. (2005) for the intermediate-old ones, we characterize the superposed stellar populations that there are within these regions.
- The high spatial resolution of the instrument allows to distinguish spatially close populations and to study their relation with each other.
- We find different structures within these regions defined by stellar populations of different ages and metallicities.
- For the interpretation of data <u>we need to separate the two components, old and young stellar populations, which contribute to the observed flux.</u>

OASIS

NGC 2718

SABab, 262 pc/arcsec

NGC 4385

SB0+, 25 pc/arcsec

NGC 4900

SBc, 59 pc/arcsec

NGC 5430

SBb, 205 pc/arcsec

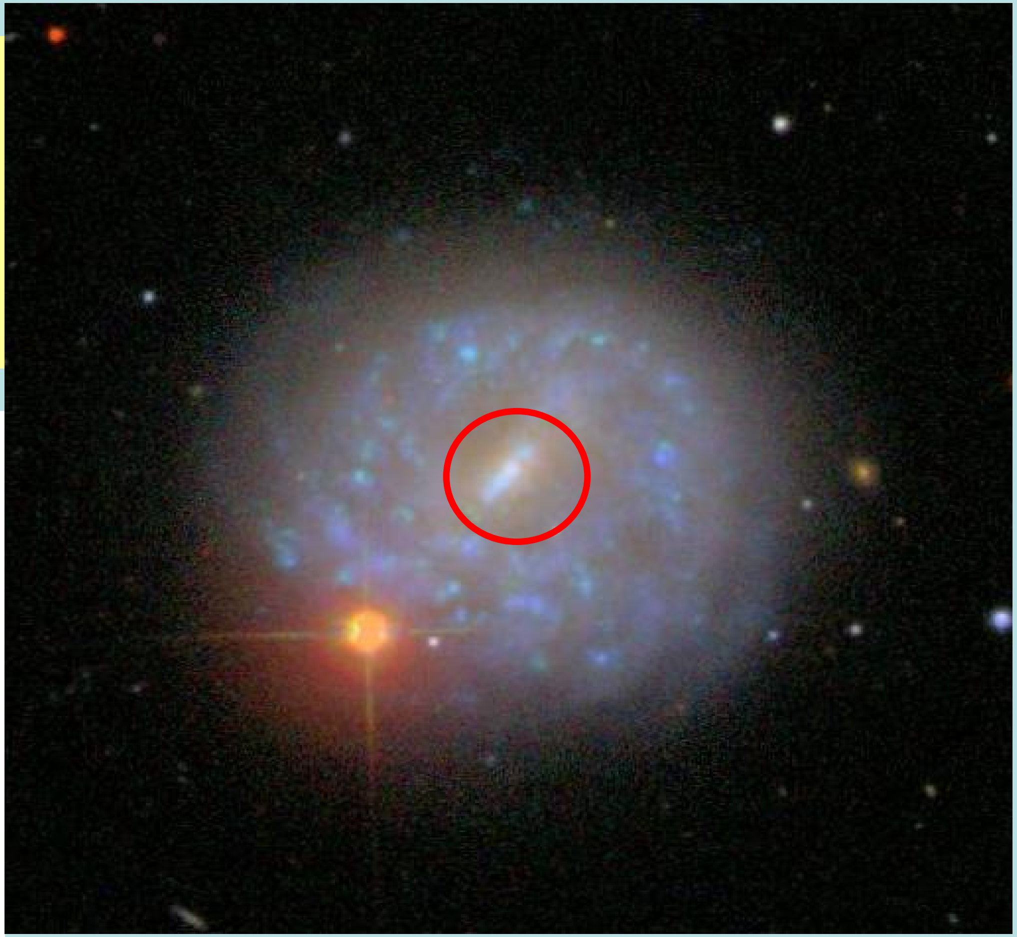
- **Imaging Spectrometer, using a microlens matrix, previously at CFHT, currently at the WHT.**
- **Data for 4 barred galaxies: NGC 2718, NGC 4385, NGC 4900 and NGC 5430**
- OASIS at the 3.6 m CFHT
  - IFU composed of a matrix of lens
  - Cassegrain f/8 mode with the EEV detector
  - Spatial resolution of 0.41"/lenset: field of view of 15"x12"
  - MR1 (4760 to 5558A) and MR2 (6210 to 7008A)
  - Spectral resolution 2.17 and 2.23 A/pixel
  - Exposure of 2400 s for each grating

Analysis of NGC 4900 data

NGC 4900 is SB(rs)c galaxy

Distance=13.3 Mpc, redshift= 960 km s^{-1} (H_0=72 km s^{-1} Mpc^{-1})

Without interaction, no peculiar activity



500 pc

Stellar Populations in the Central Region of the Barred Spiral Galaxy NGC 4900

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ABSTRACT
We present OASIS observations obtained at the Canada-France-Hawaii Telescope for the SB(rs)c galaxy NGC 4900. About 800 spectra in each of the wavelength ranges 4700-5500 Å and 6270-7000 Å have been collected with a spatial resolution of ~ 60 pc. This galaxie is part of a sample to study the stellar populations and their history in the central region of galaxies. In this paper, we present our iterative method developed to describe with consistency the different stellar components seen through emission and absorption lines. In NGC 4900, the emission lines indicate many young bursts of star formation distributed along the galaxy large scale bar on each side of the nucleus. They represent nearly 40% of the stellar mass in the field of view. The age for these bursts range from 6 to 8 Myr with a metallicity about 2$Z_\odot$. The extinction map gives values of E(B−V) from 0.19±0.01 near the youngest bursts to 0.62±0.06 in a dusty internal bar perpendicular to the large scale bar. The Mg_2 and Fe I absorption lines indicate an older stellar population in the background with an average age of 780 Myr and a sub-solar metallicity. We propose that the older episode of star formation is the consequence of a past interaction while the more recent bursts are related to the evolution of the galaxy large scale bar. Without the iterative method, we would have misted the composite/transition activity in the galaxy nucleus and the population parameters would have been substantially different, mainly in the case of the older population.

Key words: Galaxies: stellar content – Galaxies: spiral – Galaxies: individual: NGC 4900

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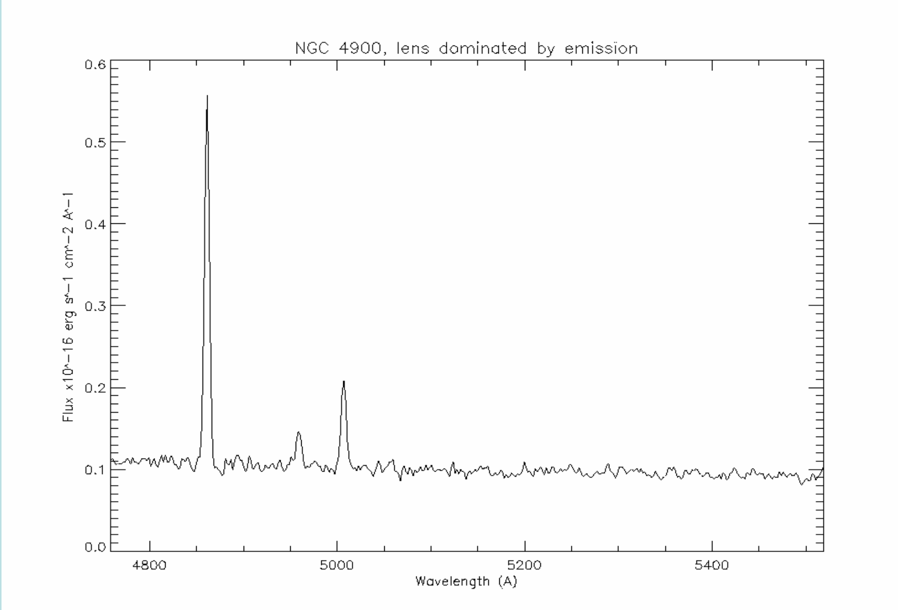
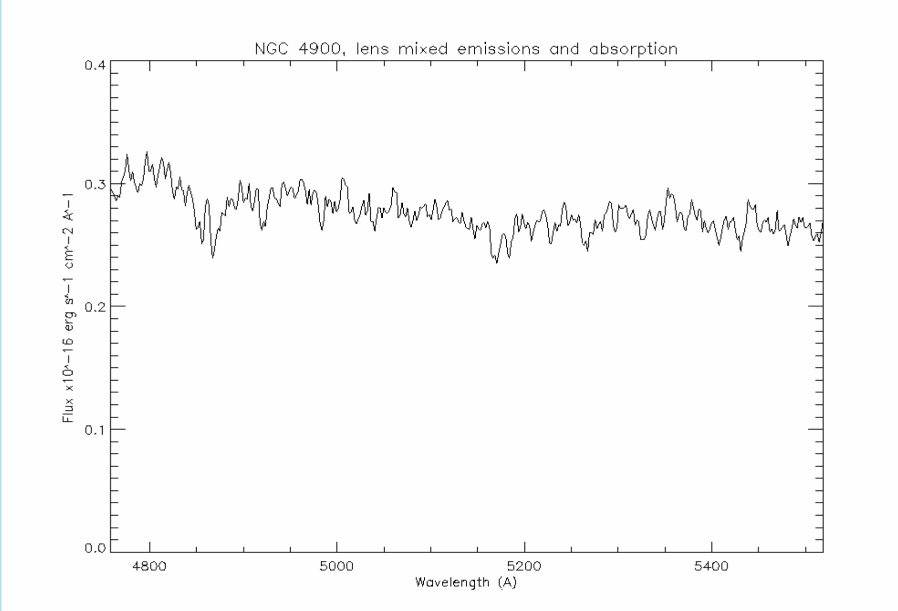
DATA REDUCTION

- XOASIS package (version 6.0),developed in the CRAL-Obs. de Lyon by Ferruit & Emsellem
- Steps:
  - Inversion of images
  - Remove the overscan
  - Substraction of dark currant
  - Substraction of the bias
  - Mask extraction
  - Wavelength calibration
- Datacube with ~800 spectra/galaxy
  - Flat field correction
  - Cosmic rays
  - Substraction of sky background
  - Flux calibration
  - Galactic reddening with a Seaton law E(B-V)=0.024
  - Rest frame
  - Reduction of 0.41” to 0.8” (seeing limit)





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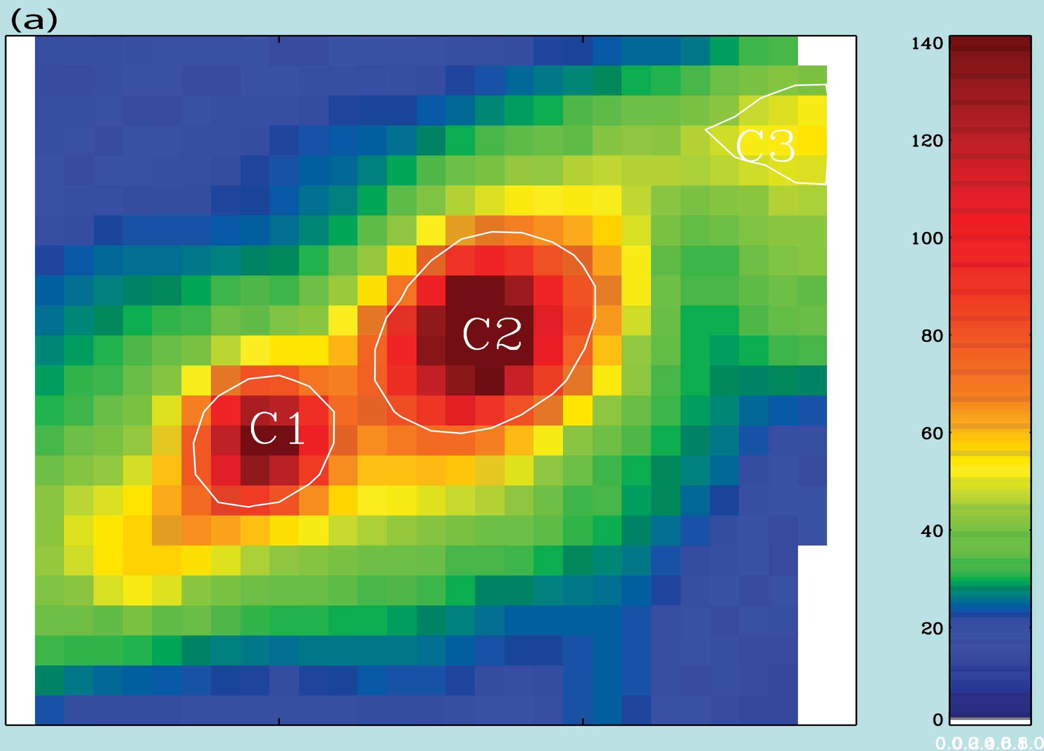
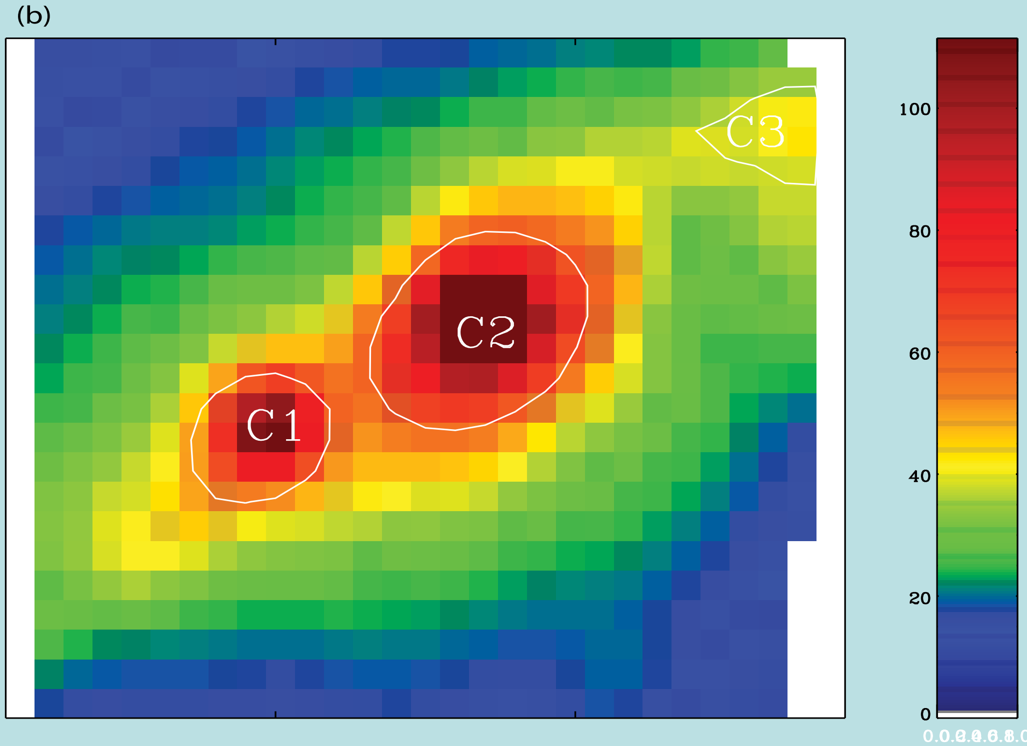
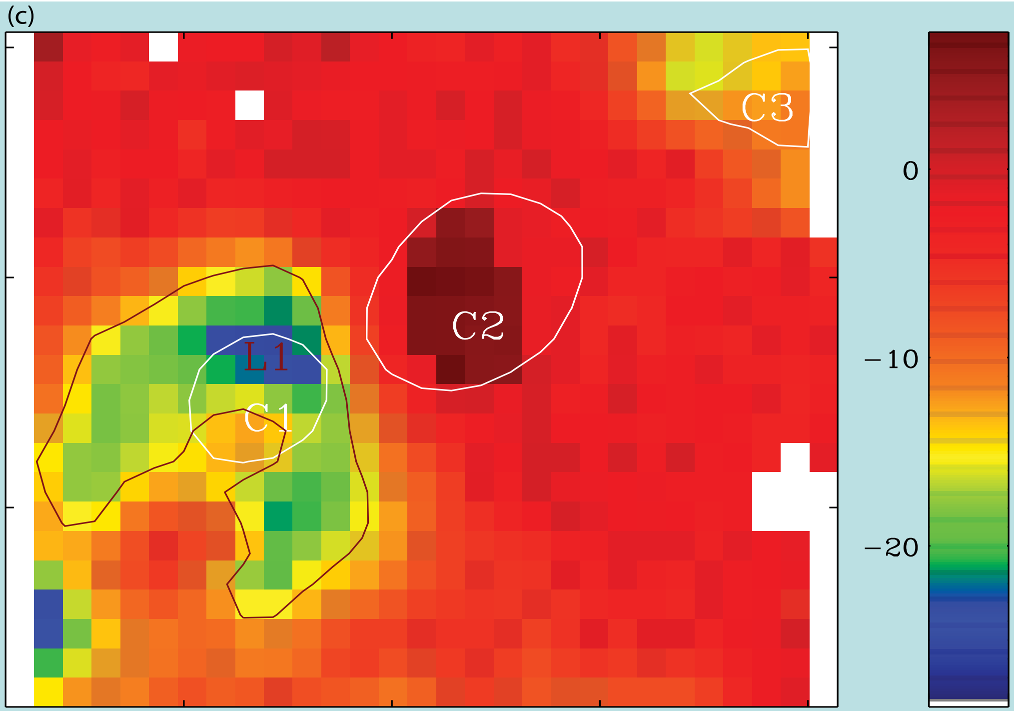
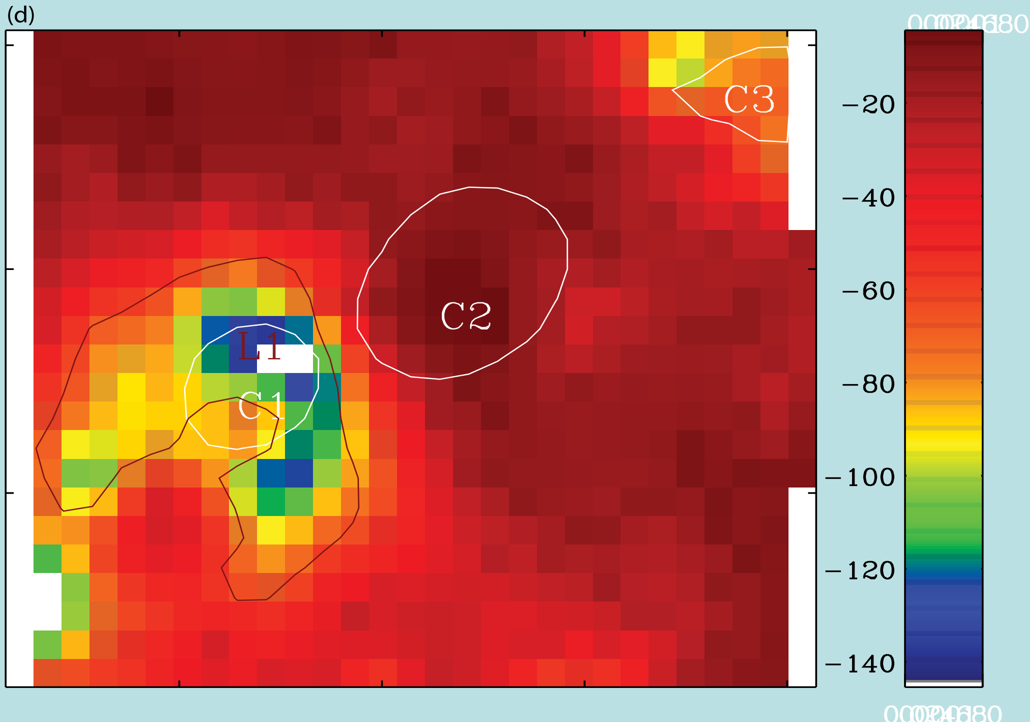
Continuum emission maps

- Structure of the central region
- Three peaks C1, C2, and C3
- They are located along the bar





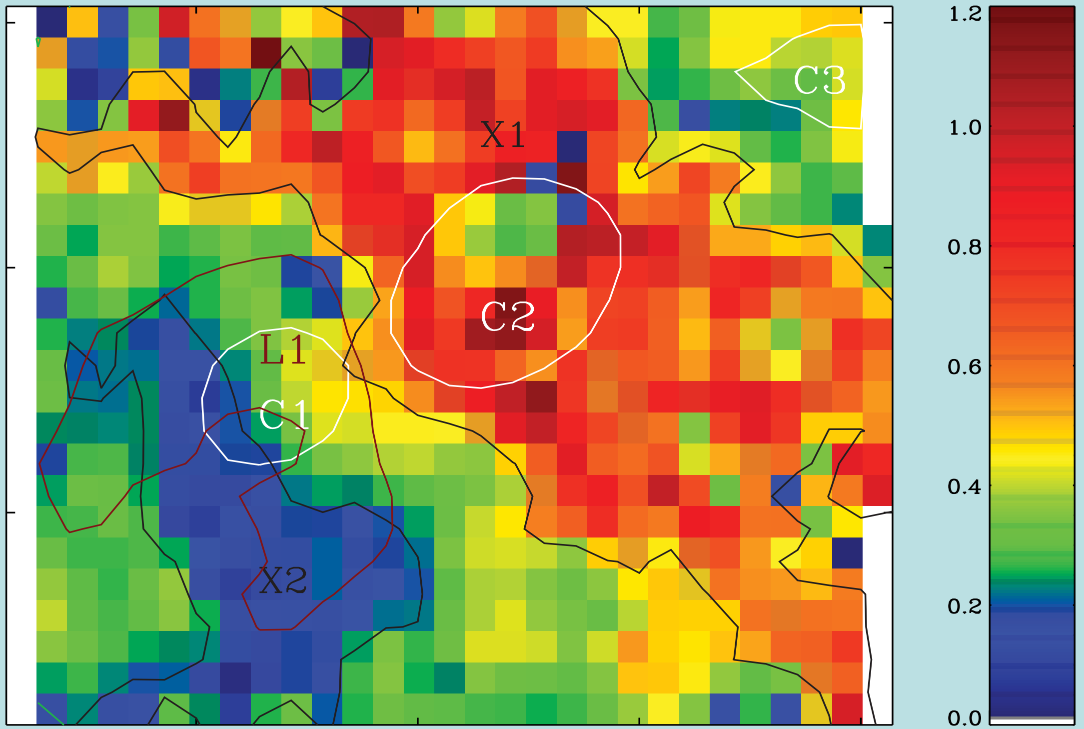




Extinction

H_α and H_β equivalent widths

- Peak around C1 and C3
- C2: absorption
- Map of extinction: <E(B-V)>=0.47



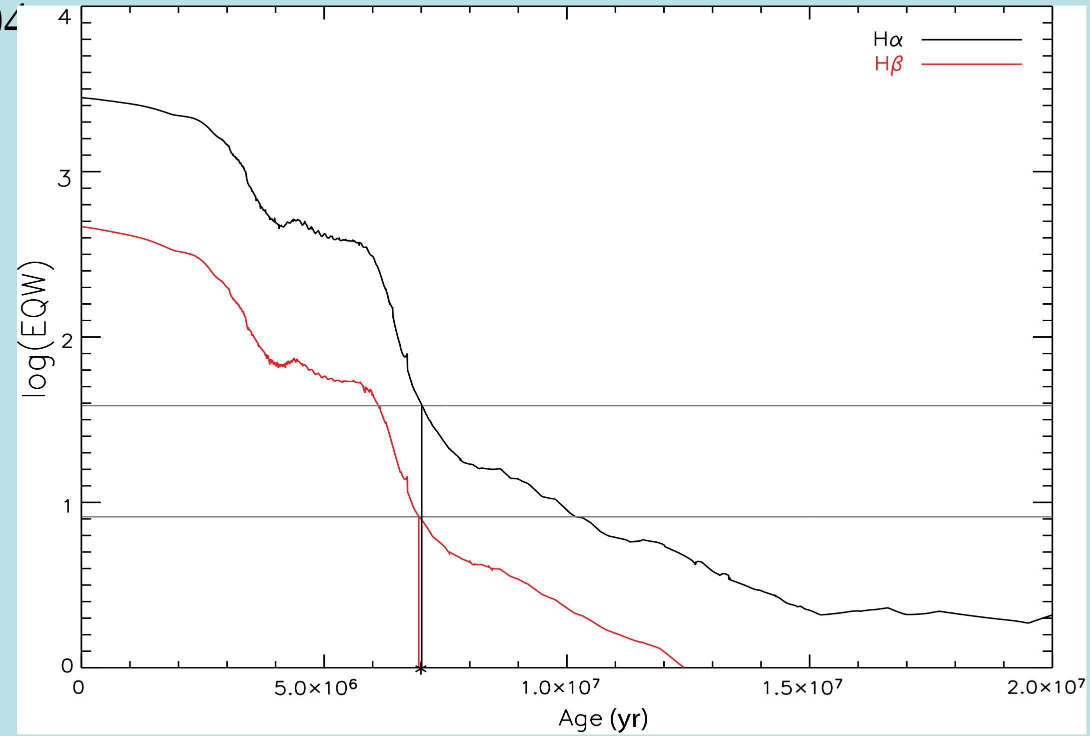
Objectives

We analyze the information proceeding from the gas and the stars in the center of barred galaxies in order to:

1. Separate the stellar populations in the centre of galaxies
2. Characterize the metallicity and age of these populations
3. Characterize the gas around those populations
4. Identify how the various populations are spatially related to each other
5. Build scenarios about the evolutionary history of these central regions

Young Populations: emission lines analysis

- Kewley & Dopita (2002): Oxygen abundances
- LavalSB:
  - Geneva isochrones
  - 4 metallicities: Z=0.002,0.005,0.02,0.04
  - IMF Salpeter 1-100 Msun
  - Nebular continuum flux
  - EW Hα and Hβ: age



Old stellar populations

Evolutionary synthesis models (Gónzalez-Delgado et al 2005):

- HR. Smoothing to the same spectral resolution than data
- Spectral indices measured on the new spectra
- Padova isochrones
- IMF: Salpeter -2.35, 1-120 Msun
- Model atmospheres

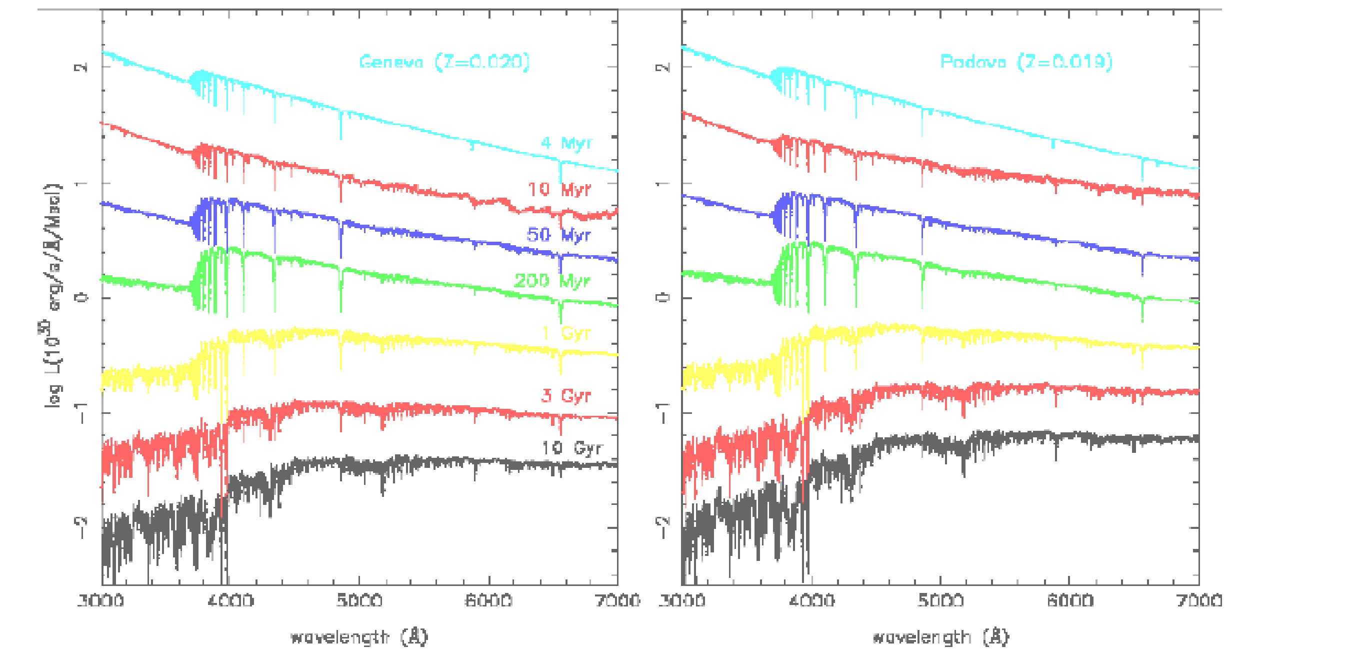
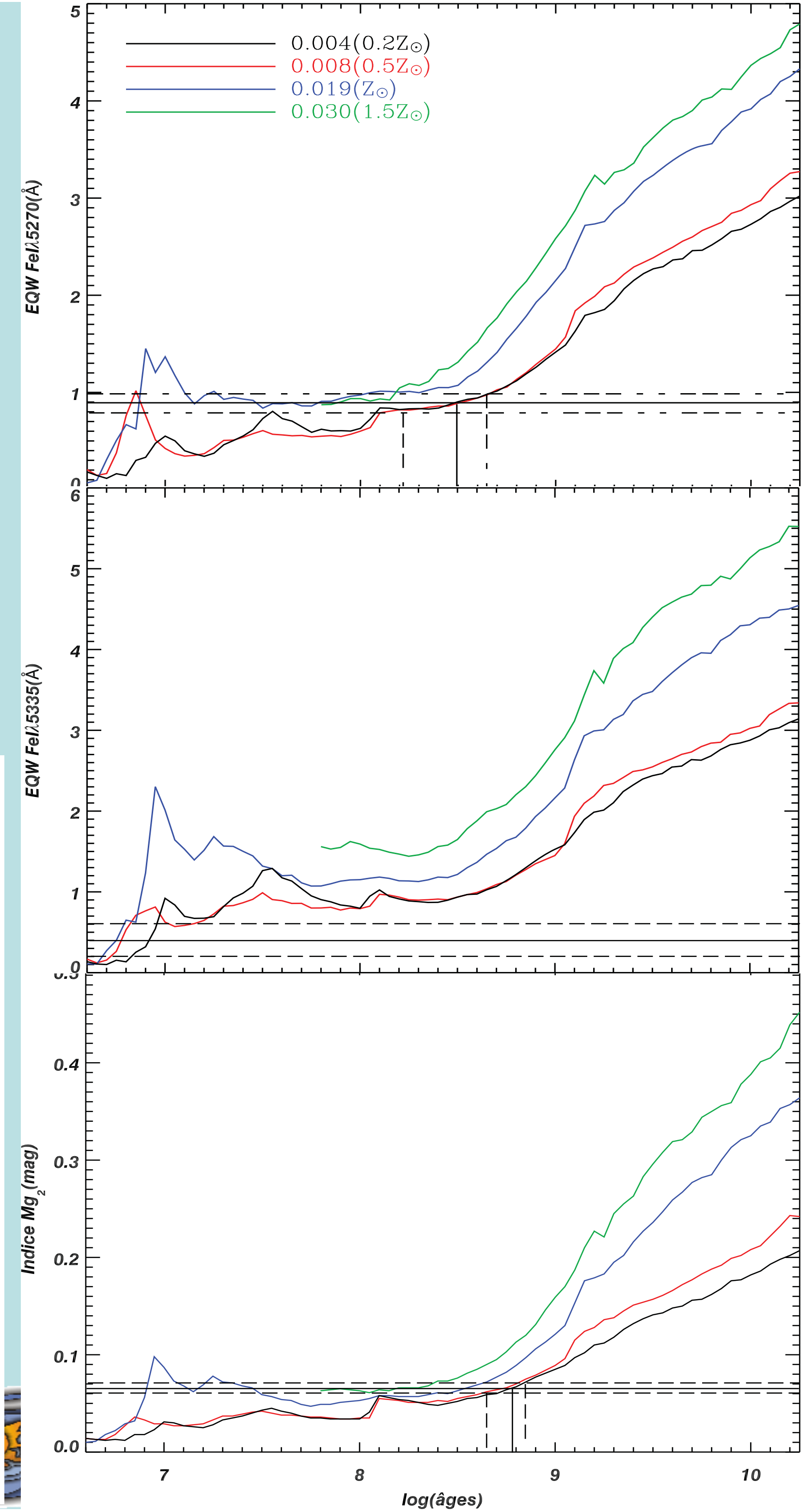
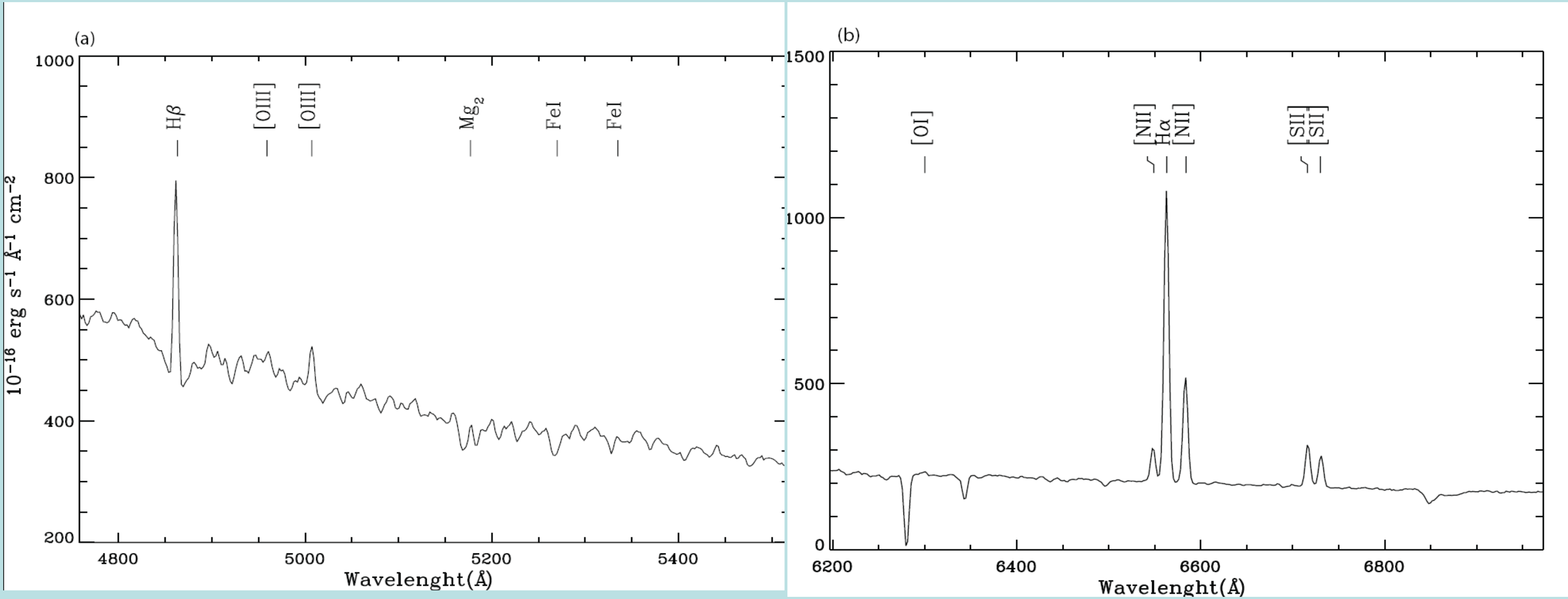


Figure 2. Spectral evolution for a single stellar population model at solar metallicity following the Geneva (left) evolutionary tracks with standard mass loss, and the Padova (right) tracks. Ages from top to bottom are 4 Myr, 10 Myr, 50 Myr, 200 Myr, 1 Gyr, 3 Gyr, and 10 Gyr.





N spectra with spatial information

Integrated spectrum obtained by addition of all datacube spectra

To extract information for each component without using the other one:

Young:
Oxygen abundance= 8.70 (Z=Zsun)
Age= 7.0 (0.2) Myr

Old:
Stellar metallicity Z=0.2-0.5 Zsun
Age= 600 (200) Myr

Young stellar populations

Gonzalez-Delgado (2008)

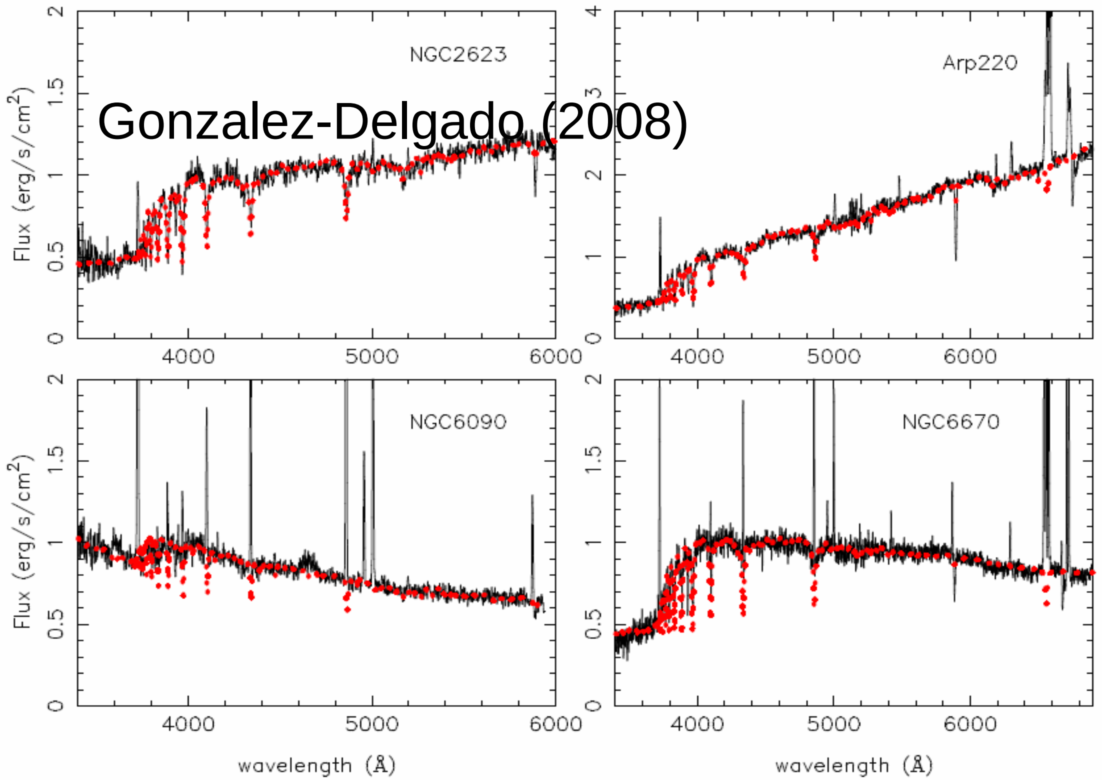
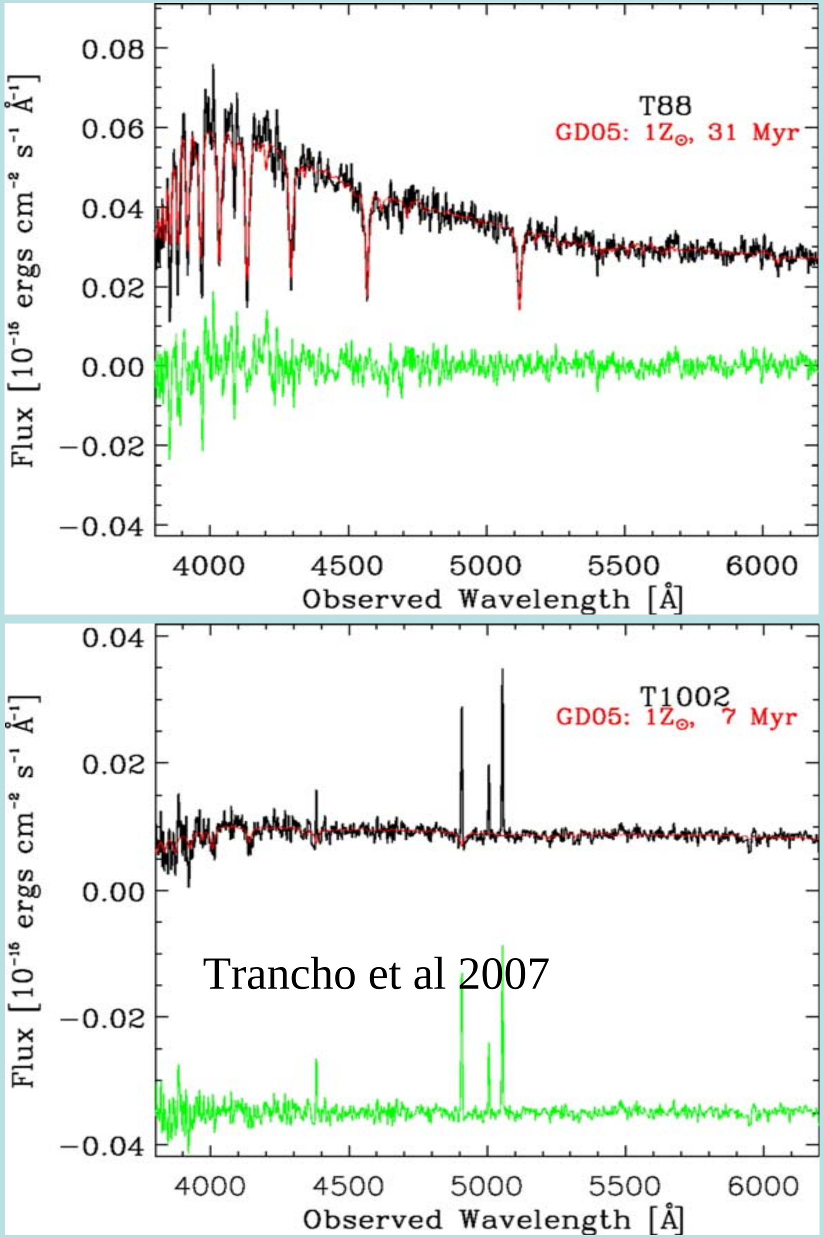


Figure 4. Optical spectra of some LIRGs (NGC6090, NGC6670, NGC2623) and the archetitypical ULIRG Arp220. The best models found with STARLIGHT and the high-spectral resolution evolutionary synthesis models from González Delgado et al (2005) are plotted as dotted lines.



Trancho et al 2007

Only young populations since there are emission lines.

Old stellar populations

The Star Formation History of Late Type Galaxies 3

Cid Fernandes (2007, astro-ph0701899)

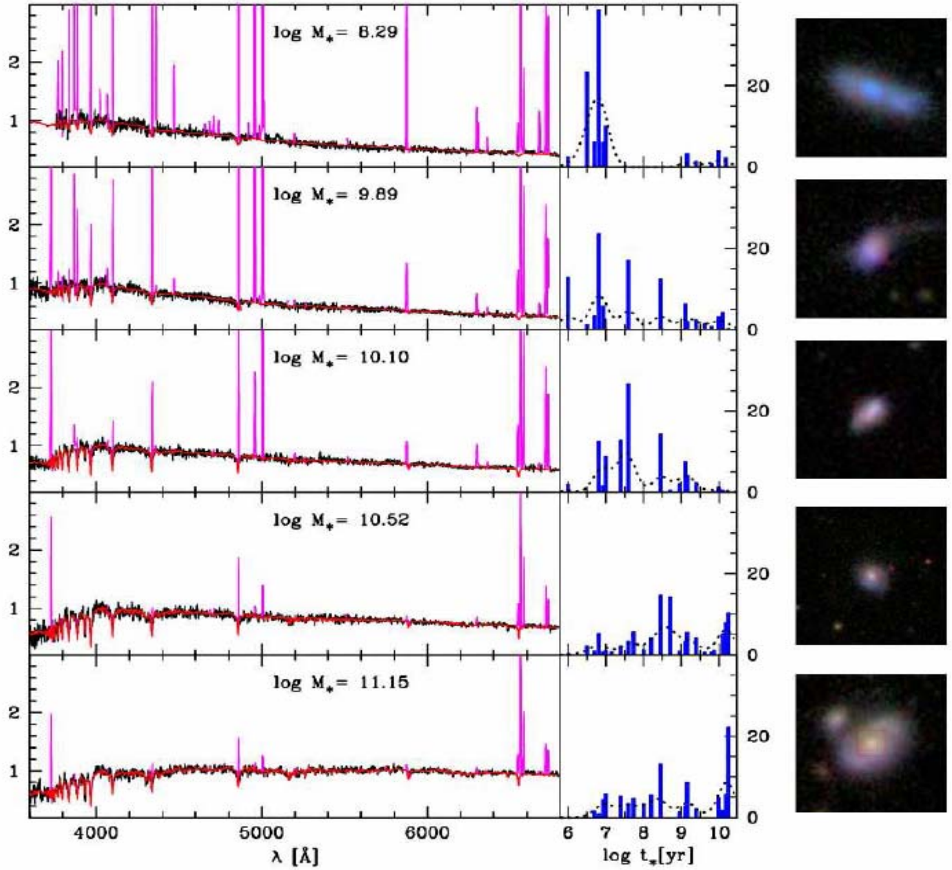


Figure 1. *Left:* Observed (black) and fitted (red) spectra of 5 SDSS star-forming galaxies at similar distances (except for the 1st, which is closer). Emission line masks are plotted in magenta. Galaxies are sorted according to their stellar mass, increasing from $10^{8.29}$ to $10^{11.15}$ $M_\odot$ from top to bottom. *Middle:* SFH, given in terms of the light fraction at 4020 Å associated with each of the 25 ages included in the fits and marginalizing over Z. Dotted curves show a 0.5 dex gaussian-smoothed version of the population vector $\vec{x}$. Notice how the balance between recent and past star-formation changes in pace with the $M_\star$ sequence. *Right:* SDSS image.

- To eliminate the emission lines…
- and to assume that no young (τ < 500 Myr) stellar populations there exist

The (in)consistency of the method

- The dilution of the absorption lines by the flux from young stars is not taken into account: age and metallicity may be bad determined

- The continuum flux estimated to obtain H_β in emission may be affected by the absorption due to the old age component and consequently the gas abundances may be wrong

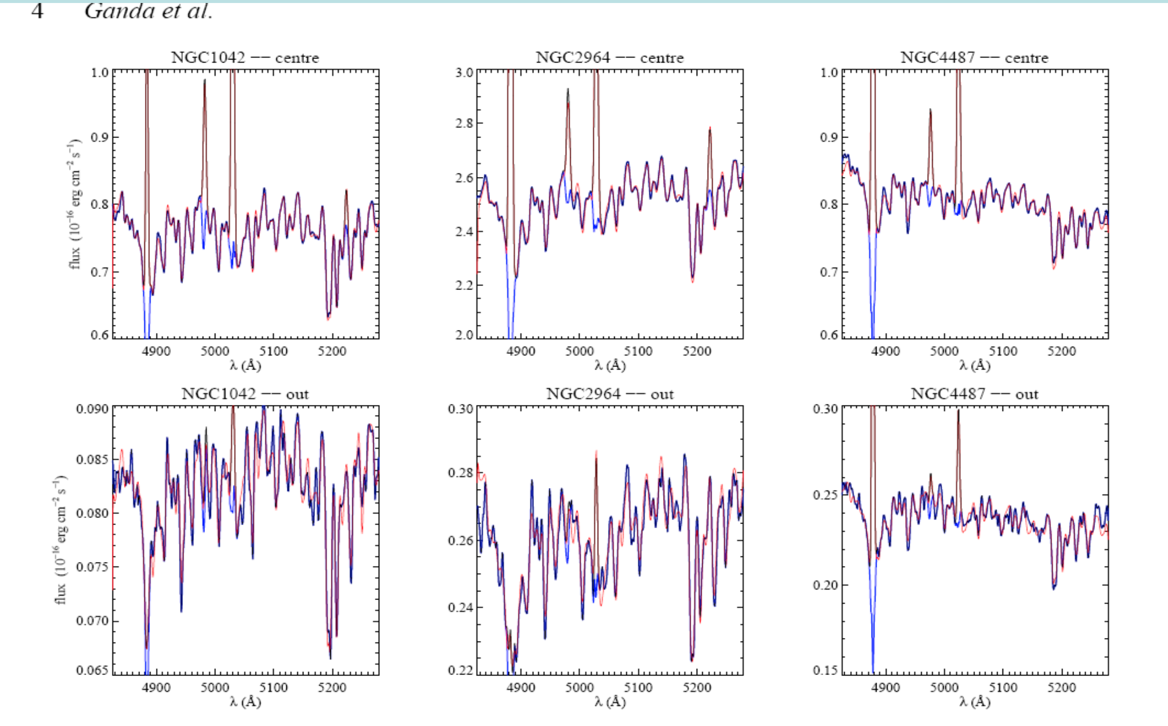


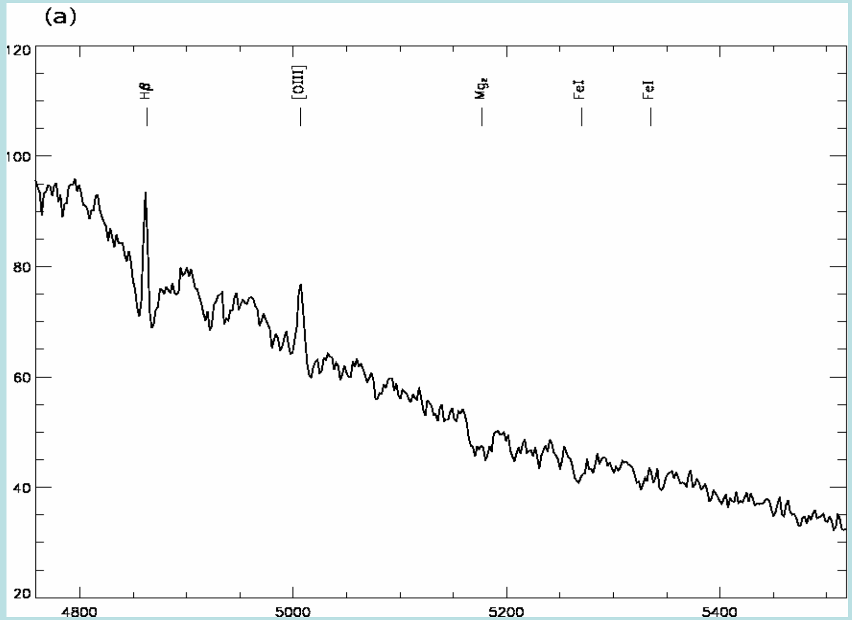
Figure 1. Top row: central aperture spectra of some representative galaxies in our sample: from left to right, we plot NGC 1042, 2964 and 4487. Along the vertical axis, the flux is in units of 10^{-16} erg cm^{-2} s^{-1}. The black lines -hardly distinguishable from the other ones- represent the observed spectra; the red ones the best-fit and the blue ones the spectra after emission removal. Bottom row: as in the top row, but for bins located ≈ 10″ away from the galaxy's centre.

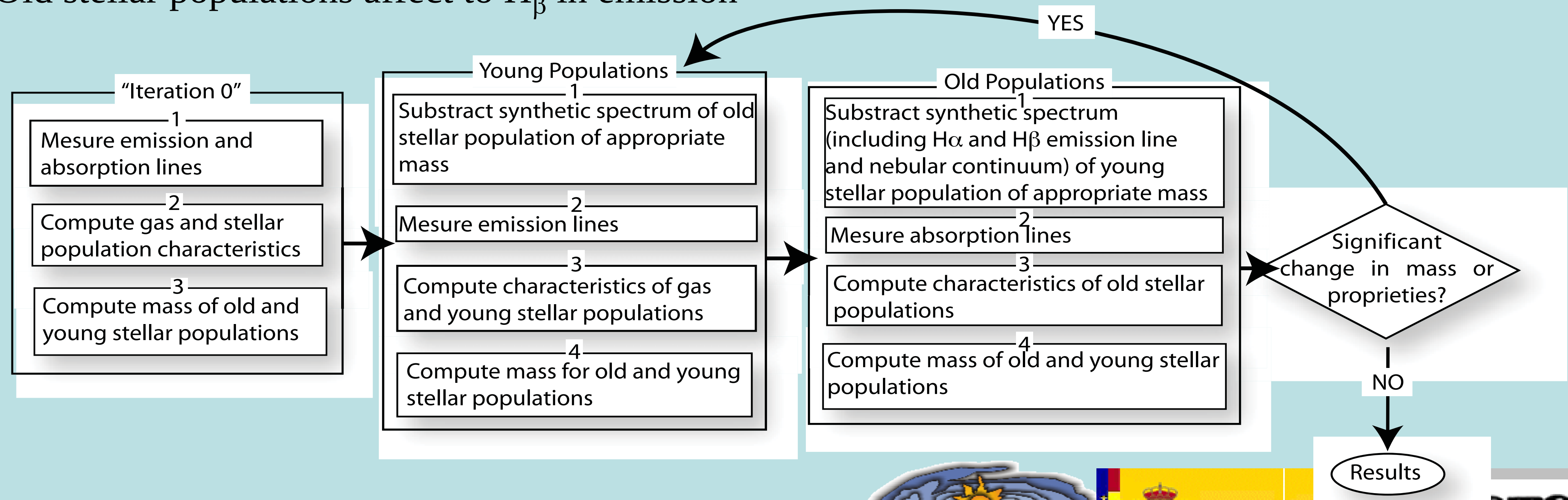
Ganda et al. (2007), SAURON

•It is necessary to find the correct proportion of young and old stellar population masses to estimate certainly their age and metallicity

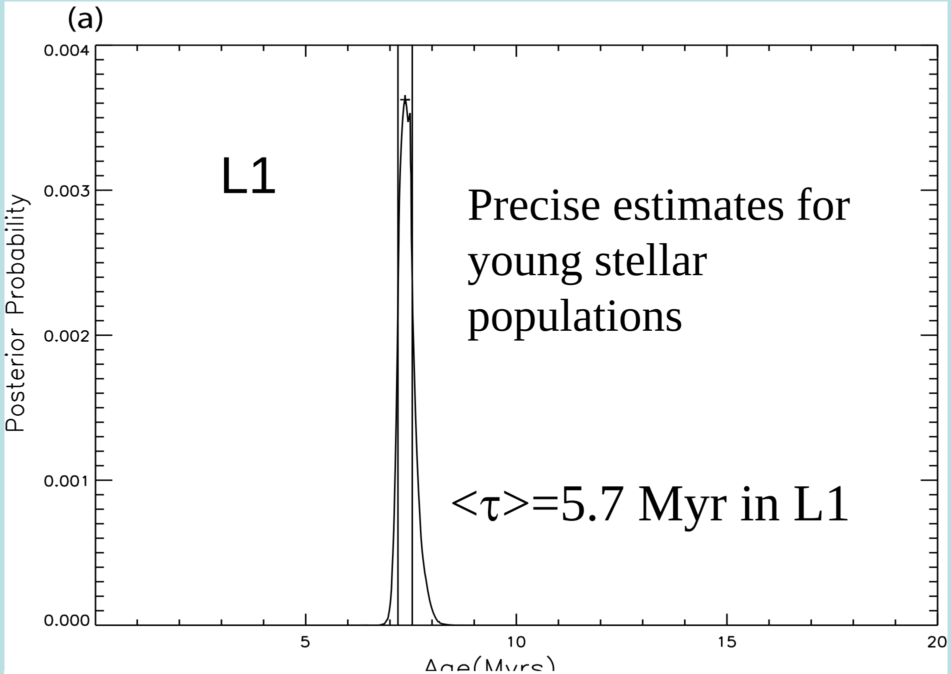
Iteration technique: consistent results

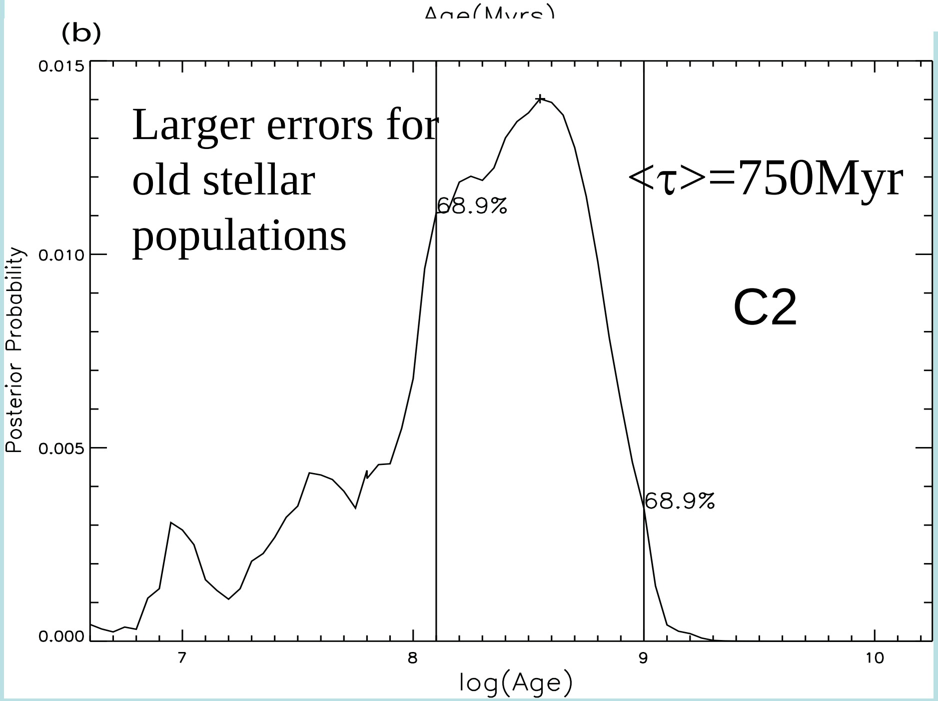
- To separate both stellar populations
- To determine age, metallicity and mass of each component
- Bayesian stadistic code to select the best model from absorption/emission lines
- Young stellar populations dilute the absorption lines
- Old stellar populations affect to H_β in emission

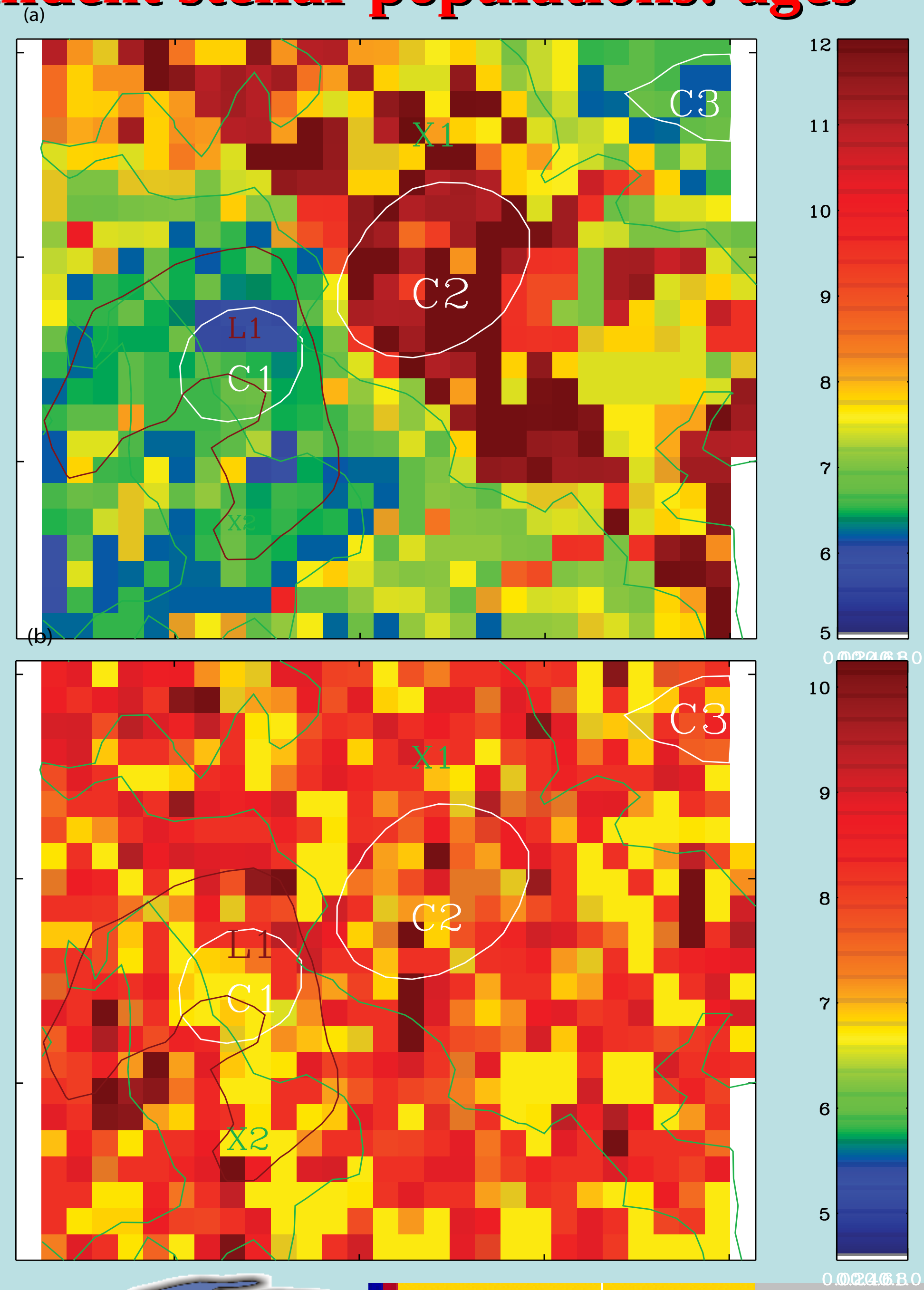




Preliminary Results with 2 independent stellar populations: ages



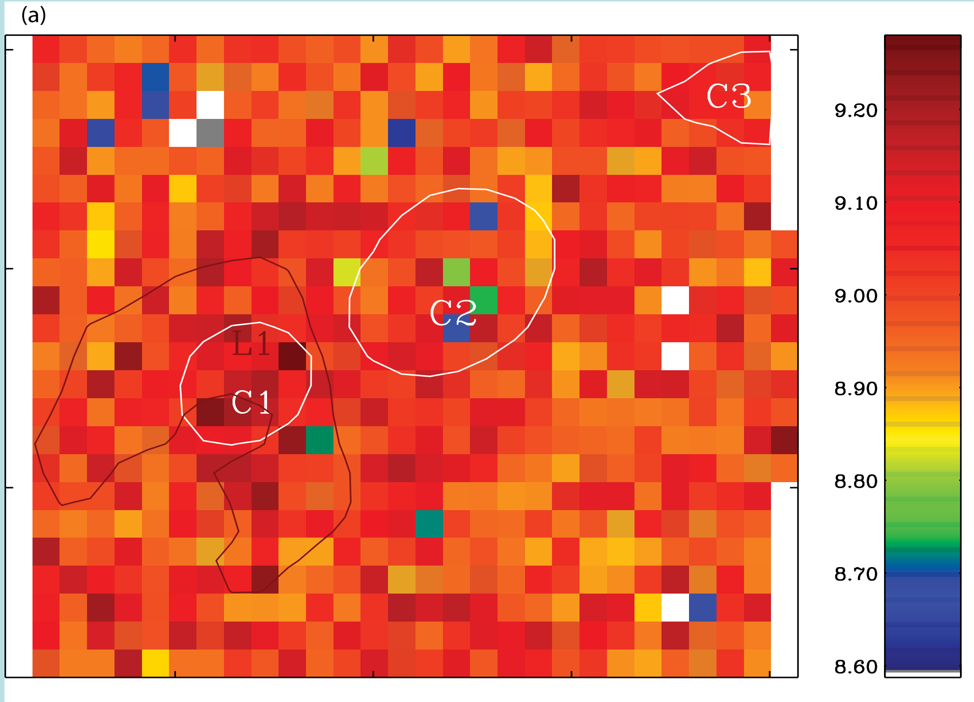


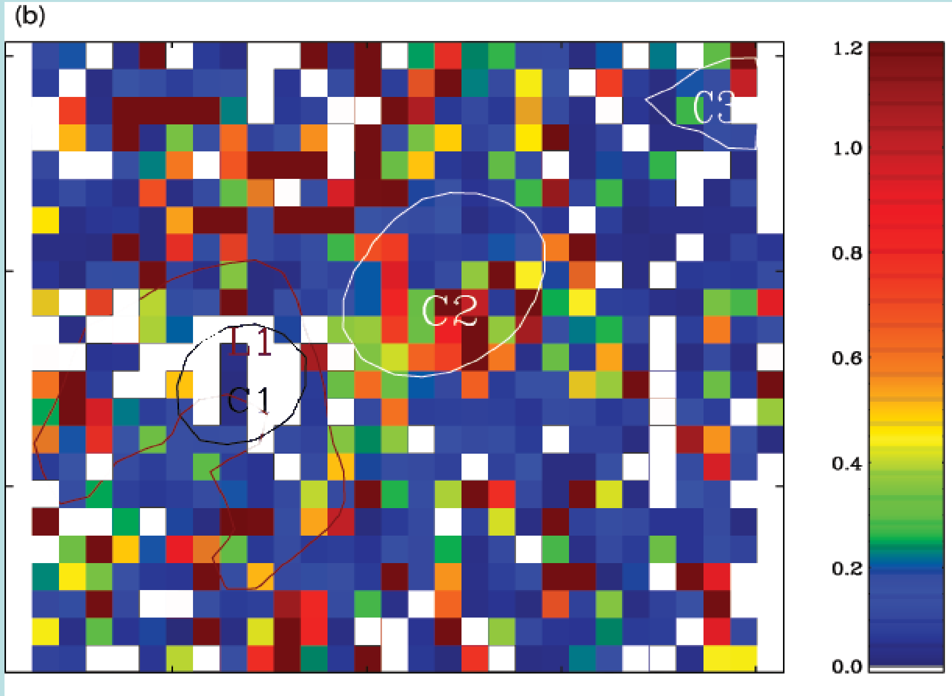


Estallidos with Integral Field Units. Granada 2009

Preliminary Results: Metallicity

- Oxygen abundances for the gas from emission lines: ~2 Zsun on the center
- Stellar metallicity from the spectral indices: larger uncertainties, around 0.2 Zsun



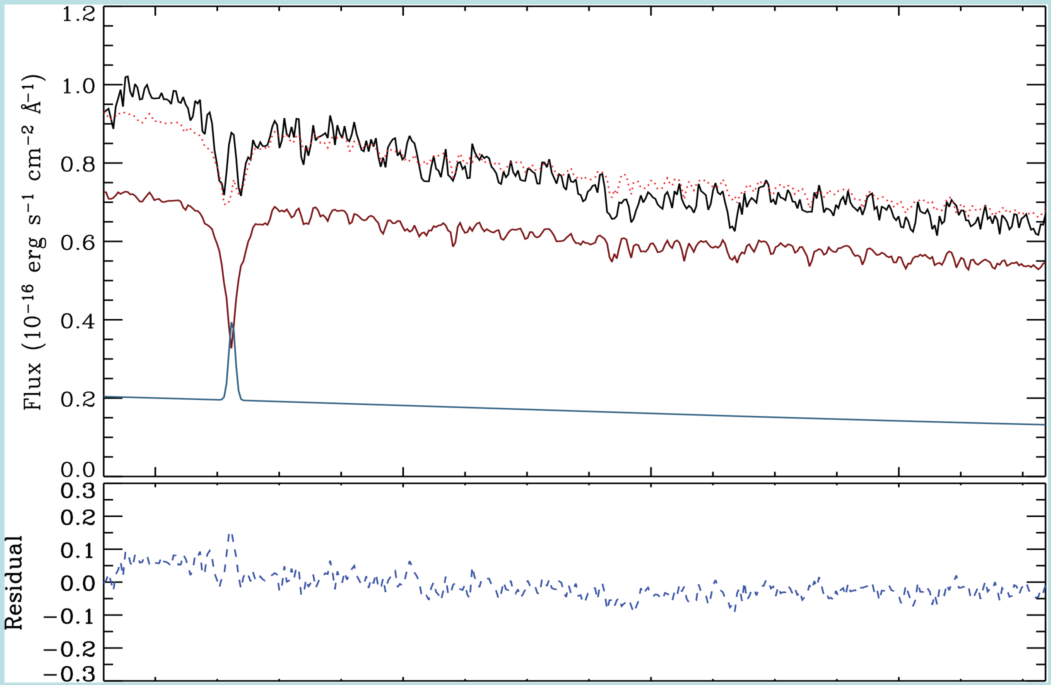


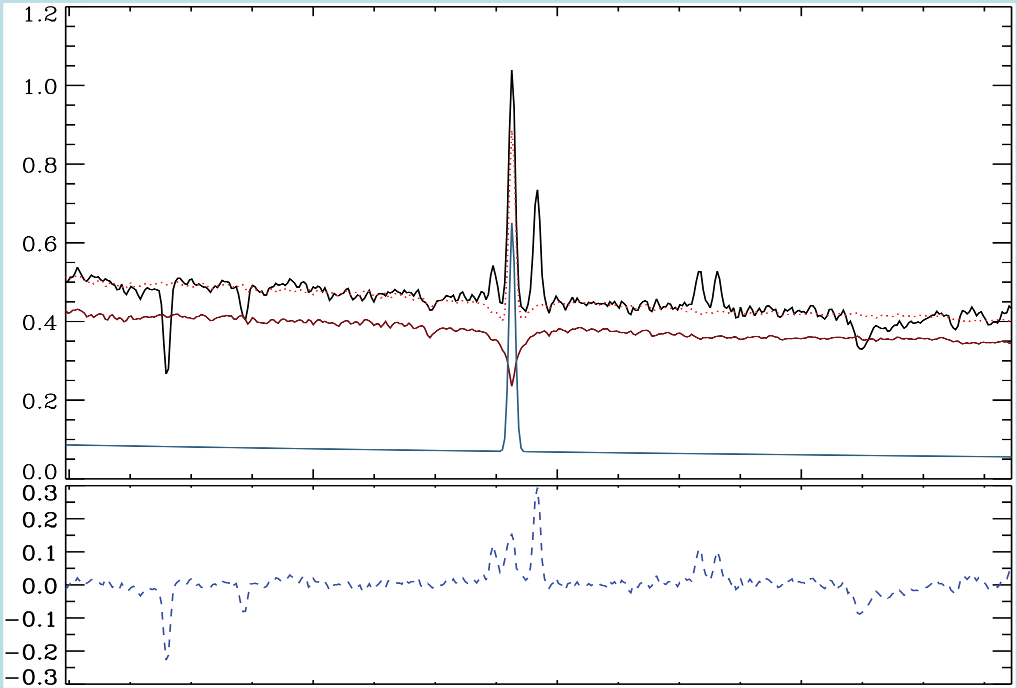
Final Results

- Ages, metallicities and stellar masses from each spectrum
- Region C2: dominated by an old stellar population

Young:
Oxygen abundance=9.0 (Z=2Zsun)
Age= 8.0 (0.2) Myr
Stellar mass= 8000 Msun

Old:
Stellar metallicity Z=0.2 Zsun
Age= 3.0 Gyr
Stellar Mass: 3.10^5Msun





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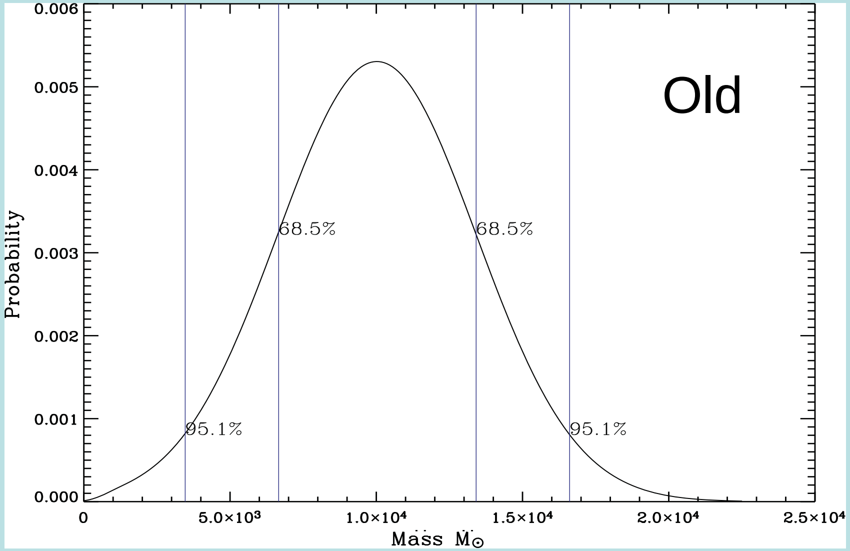
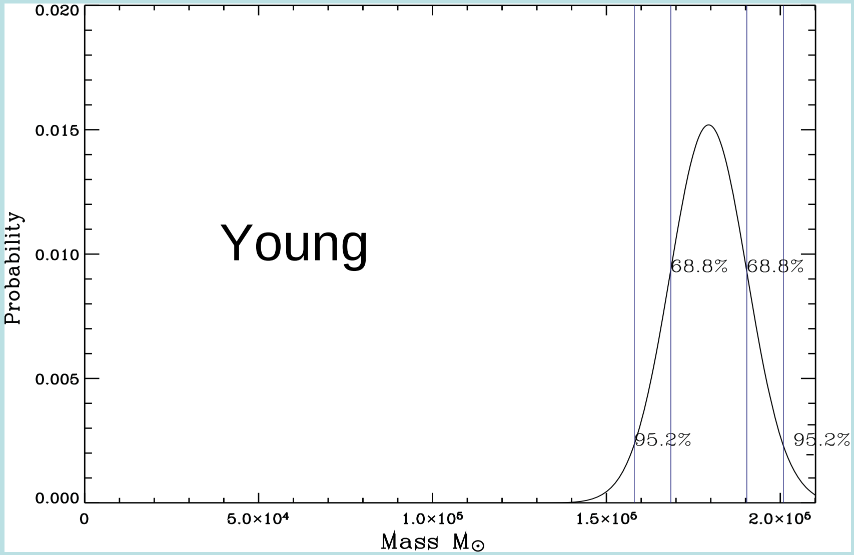
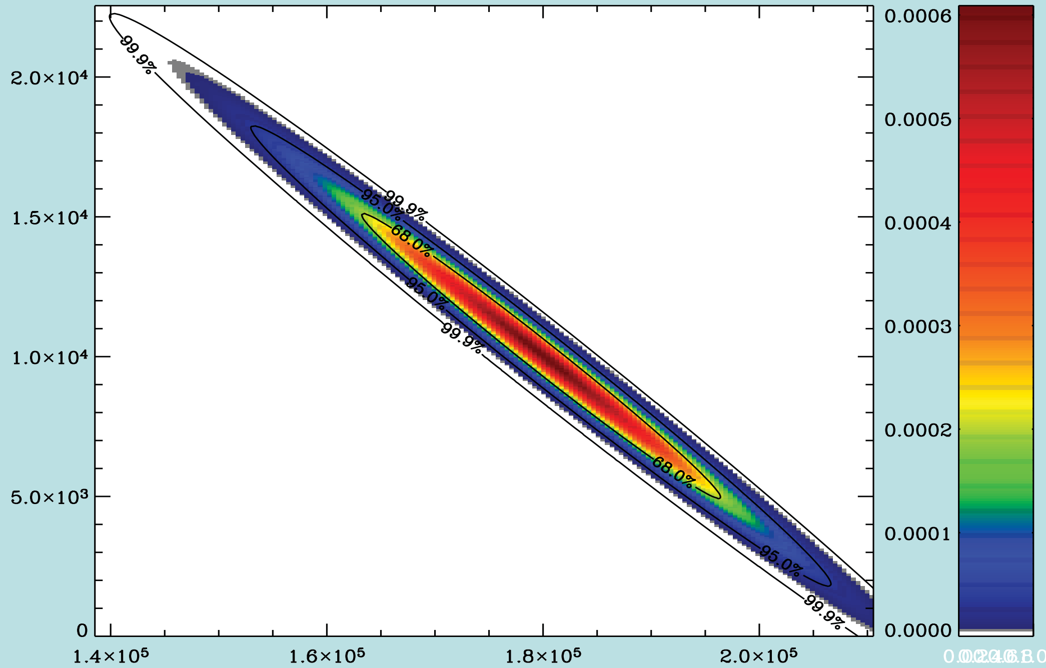
Mass of stellar populations



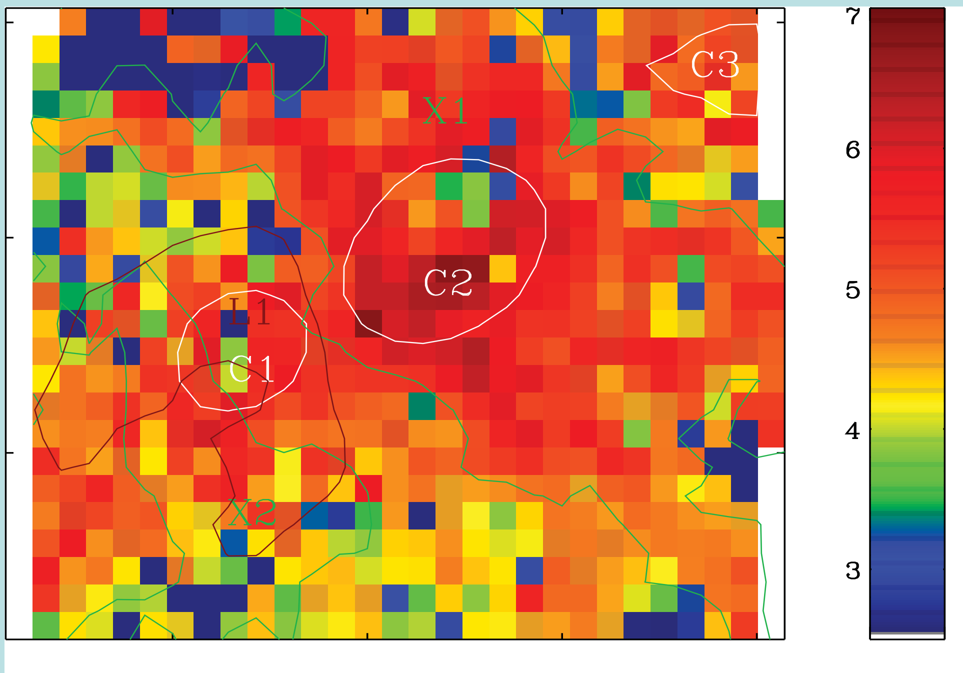


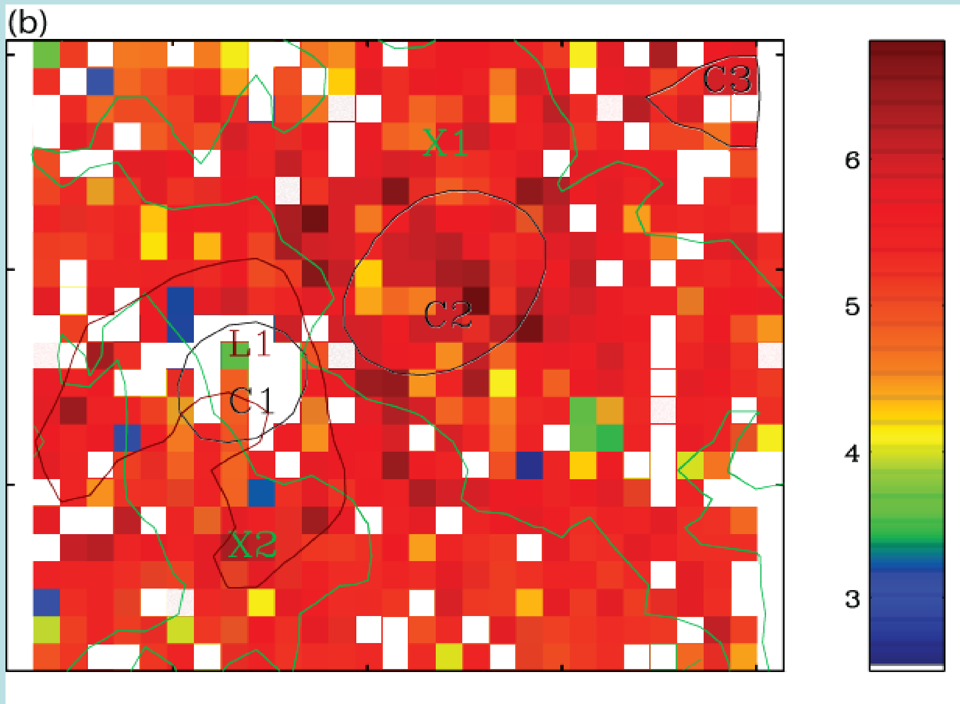


Determination of the best proportion to fit each spectrum

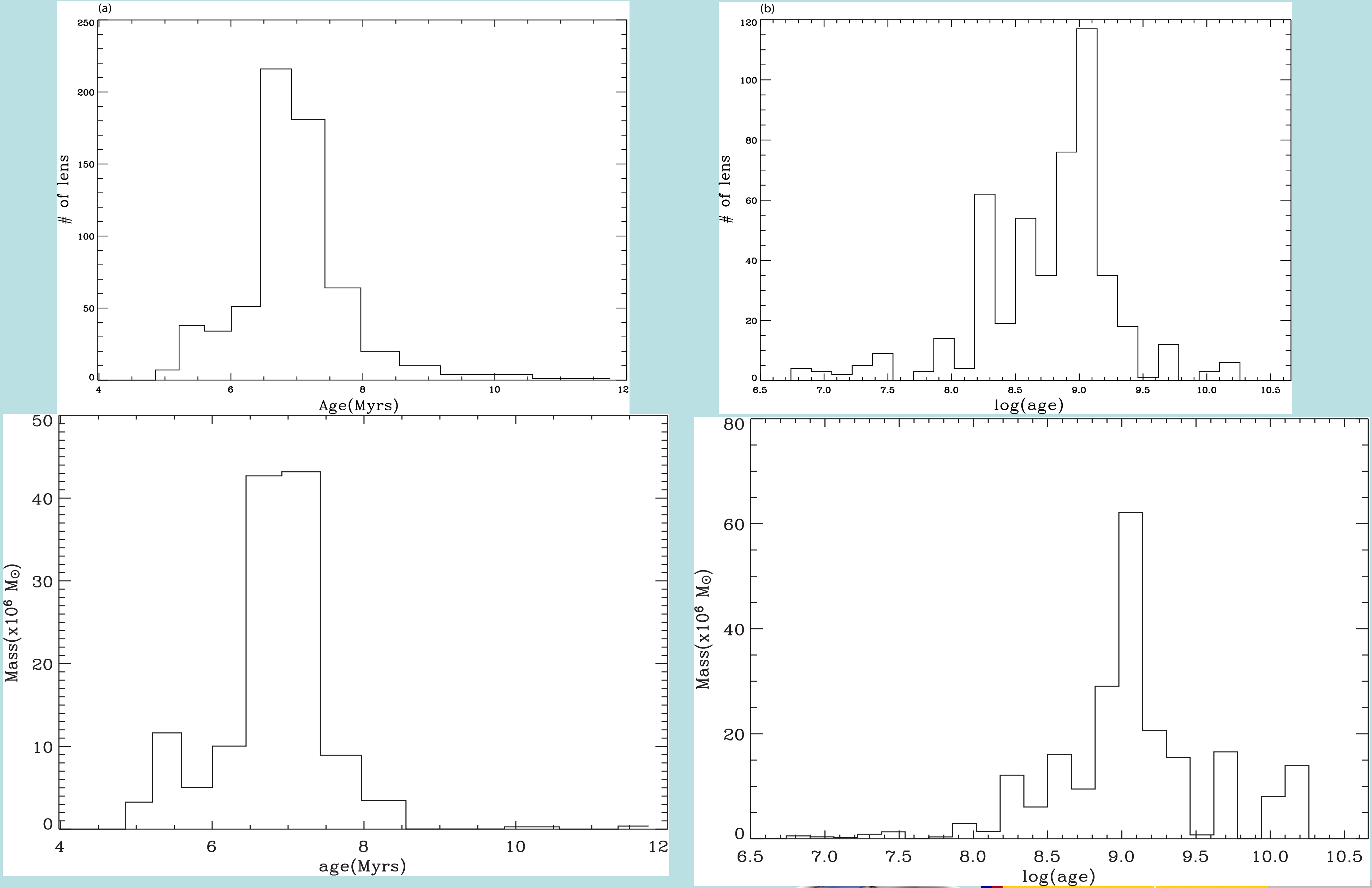
Mass of stellar populations

- In C1 and C2 there is a mass of young stars of $5x10^5$ Msun by spectrum, which means a density of 50 Msun/pc^2
- Outside these regions the mass is $8x10^4$ Msun/spec, with a density of 30 Msun/pc^2
- The old stellar population has similar values (y/o ~40%-60%: strong starbursts, but died stars not taken into account)





Ages distributions: the star formation history



Results for NGC 4900

- The young stellar populations have ages between 5.5 and 8 Myr with Z~Zsun (40% stellar mass)
- The old stellar population age is between 100 Myr and 3 Gyr with a maximum around 1 Gyr. Z~0.2Zsun
- A long series of multiple bursts which took place in the central region of the galaxy
- NGC 4900 hosted many star formation episodes in the relatively recent past:
  - 3 Gyr ago probably the whole central region stars was created This population may be associated with the bulge population.
  - 8 Myr ago in the dusty bar
  - 5 to 6 Myr ago along the large scale bar
- The young bursts have been triggered by a single specific event in the recent past: flow of enriched material toward the central region

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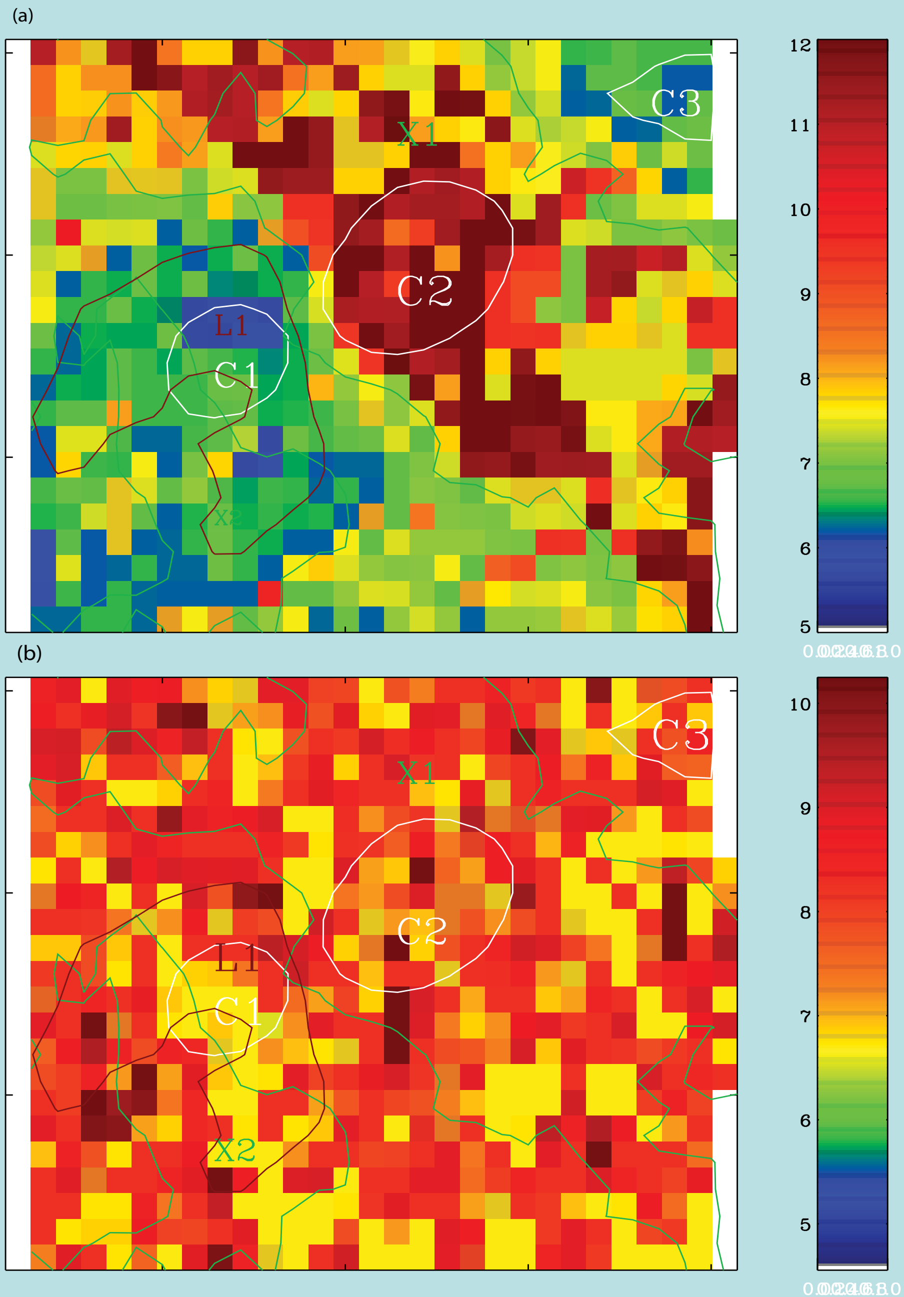
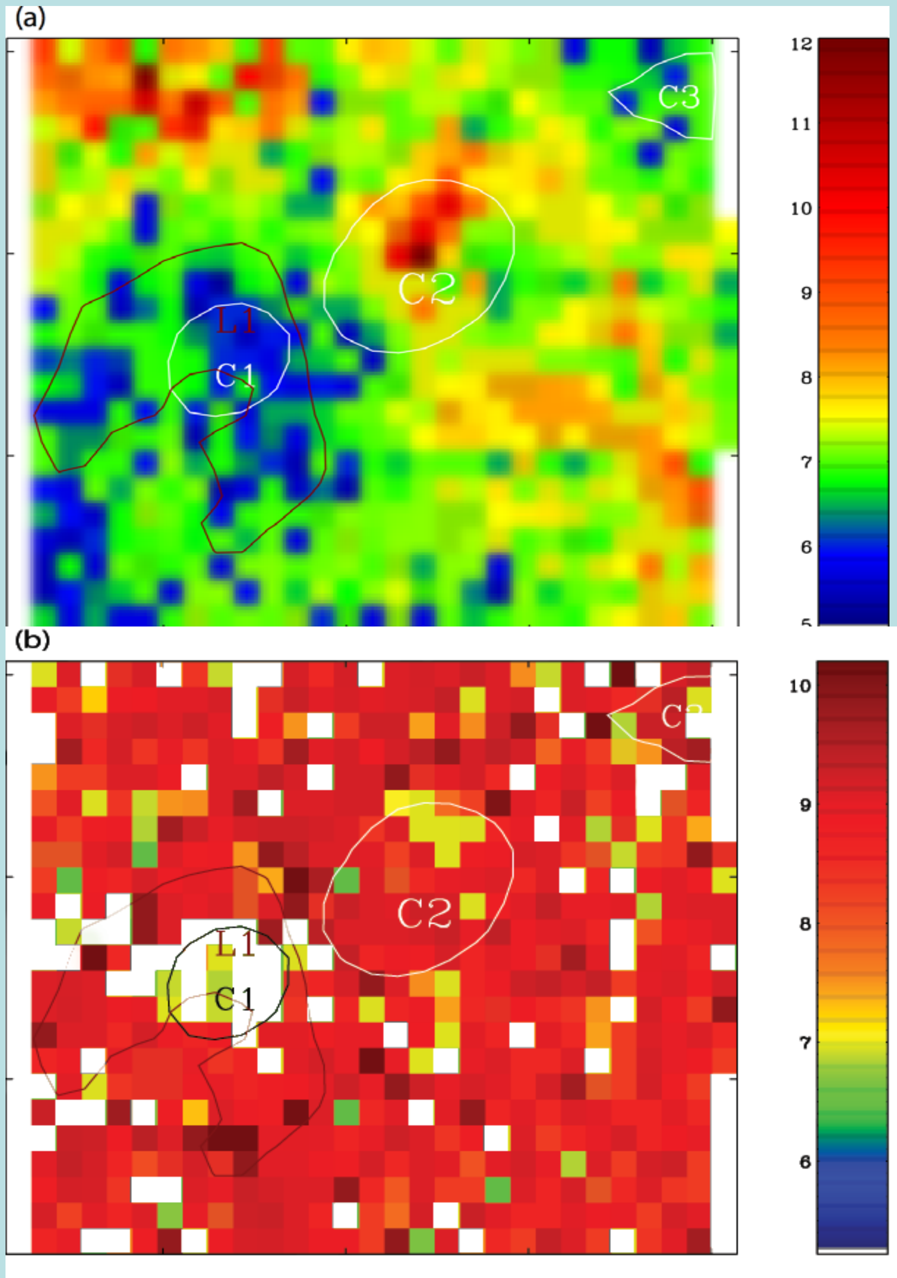
Final Results: ages comparison





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Comparison of results

Iteraction 0

Young:
Oxygen abundance= 8.7
Age= 5.7 to 12 Myr

Old:
Stellar metallicity Z=0.2Zsun
Age= 750 Myr

Final Iteraction

Young:
Oxygen abundance=8.9 (Z=2Zsun)
Age= 5.5 to 7.9 Myr

Old:
Stellar metallicity Z=0.2Zsun
Age= 3 Gyr

The results obtained for one stellar population change when the other one is also taken into account: the young ones are younger and the old ones are older in the final iteraction than in the first one.

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Summary

- We present our iteractive method to describe simultaneously the different stellar components which are apparent in the emission and absorption lines seen in the spectra obtained by OASIS.
- We show the technique and the results obtained for the central region of the barred spiral galaxy NGC 4900.
- Differences in the interpretation and results with and without this iterative technique are evident, what could imply erroneous conclusions when it (or somthing similar) is not used.
- In particular, the age of the young stellar population would have been overestimated while the age of the old one would have been underestimated

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THE PROBLEM: CAN WE INTERPRET THESE DATA IN TERMS OF EVOLUTIONARY PATHS?

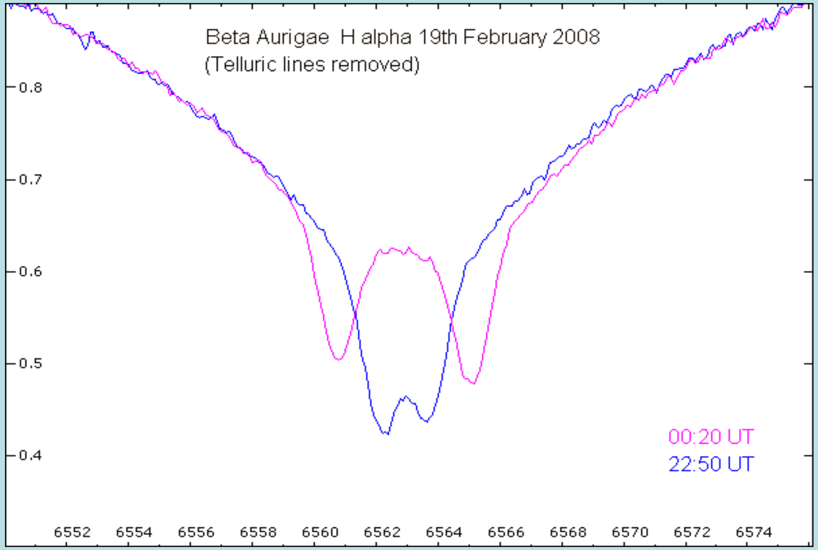
Two hypotheses:

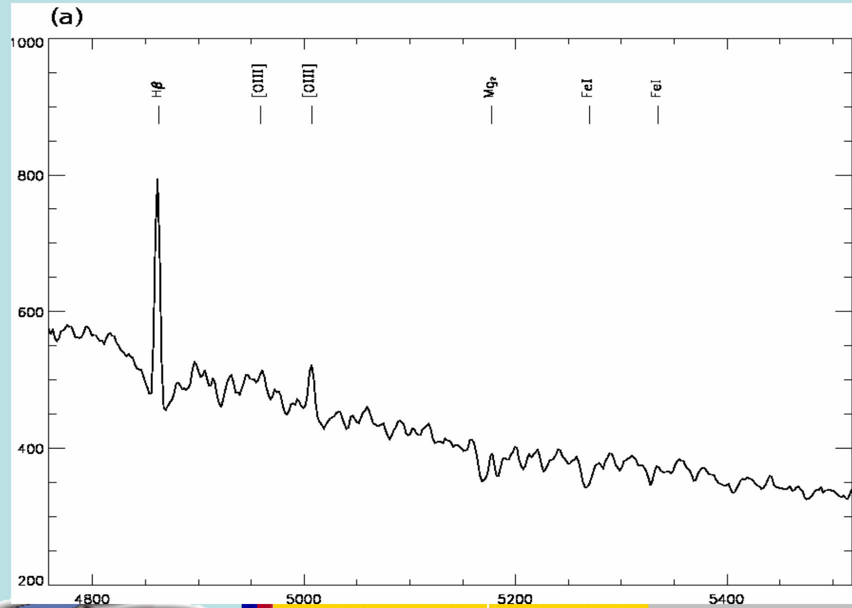
1) Two populations: there is a bulge with an old stellar population uniform in age and Z and where the bar provokes a recent infall of gas which produces a very young star burst

Classical method of using SSP´s to estimate a mean metallicity and age

2) Mixed stellar populations: There is a slow infall of gas (Domínguez-Tenreiro, Monday), implying a continous star formation history -SFH-, over an old stellar population created in a fast early phase

In that case to determine only the mean age and metallicity does not allow to estimate this star formation history or its corresponding enrichment history Z(t)





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Data

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  - Cassegrain f/8 mode with the EEV detector
  - Spatial resolution of 0.41"/lenset: field of view of 15"x12"
  - MR1 (4760 to 5558A) and MR2 (6210 to 7008A)
  - Spectral resolution 2.17 and 2.23 A/pixel
  - Exposure of 2400 s for each grating
- Data reduction: XOASIS
  - Remove overscan, substraction of the darl currant, substraction of the bias, weak fringing correction
  - Mask extraction: datacube of N spectra
  - Cosmic rays
  - Sky backgroung substraction
  - Flux calibration
  - Merging of datacube and new identification pattern
- IRAF: Galactic reddening correction