Granada, 1-Dec-2010

STELLAR POPULATIONS SYNTHESIS MODELS

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Outline

- What is a stellar population?
- Stellar populations synthesis models
- Why we need SP models?
- Ingredients and uncertainties of the models
- Methodology. How to apply models to data?
- Practical example: IC 1623 photometry
- Practical example: IC 1623 spectroscopy
- Summary

Rosa M. González Delgado SEA contribution: SP Models review

http://www.sea-astronomia.es/drupal/sites/default/files/archivos/videos/Rosa%20M%20Gonzalez%20Delgado.mp4

Simple Stellar Populations

- Simple stellar population: group of stars with same age (t) and same initial metallicity (Z)

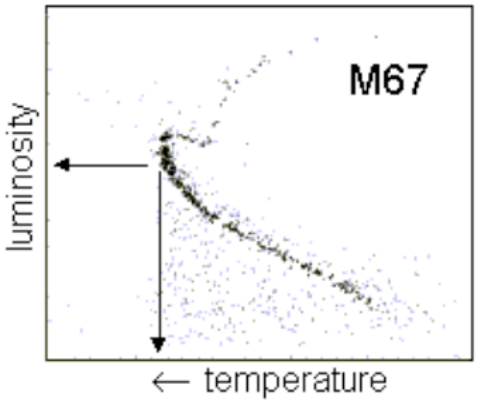
M67

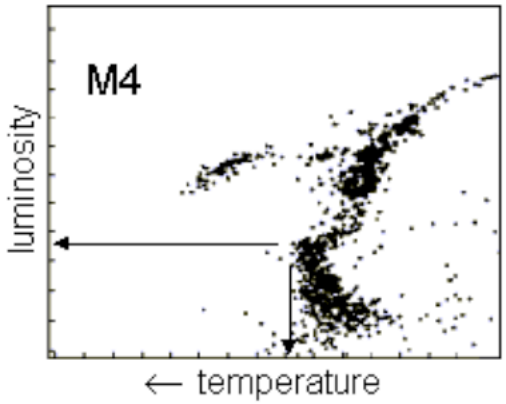
M4

Resolved Populations

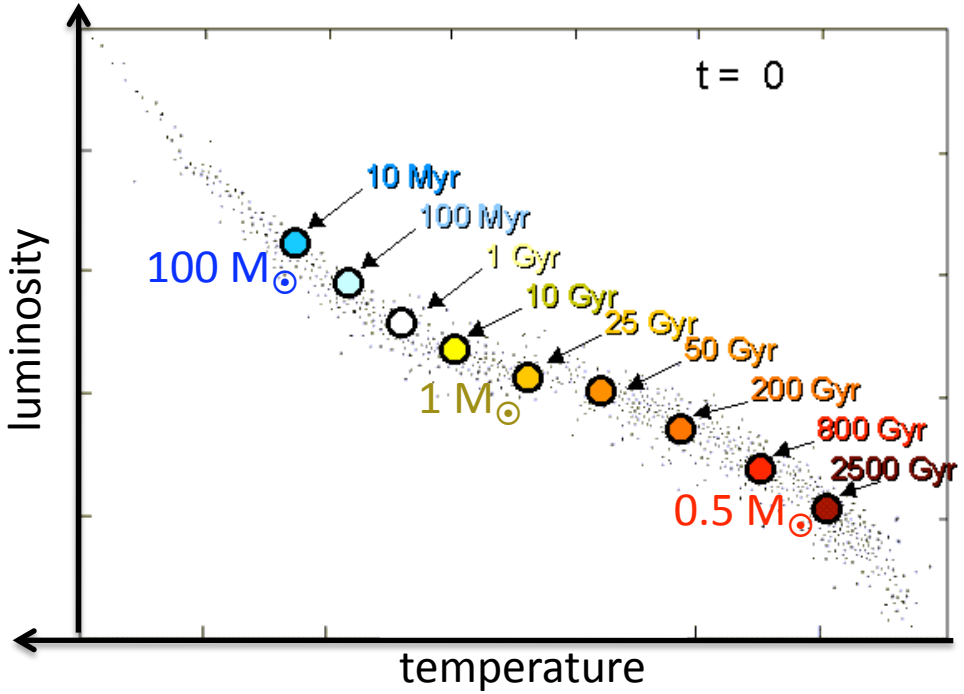
- Resolved stars, CMD diagrams

Young cluster





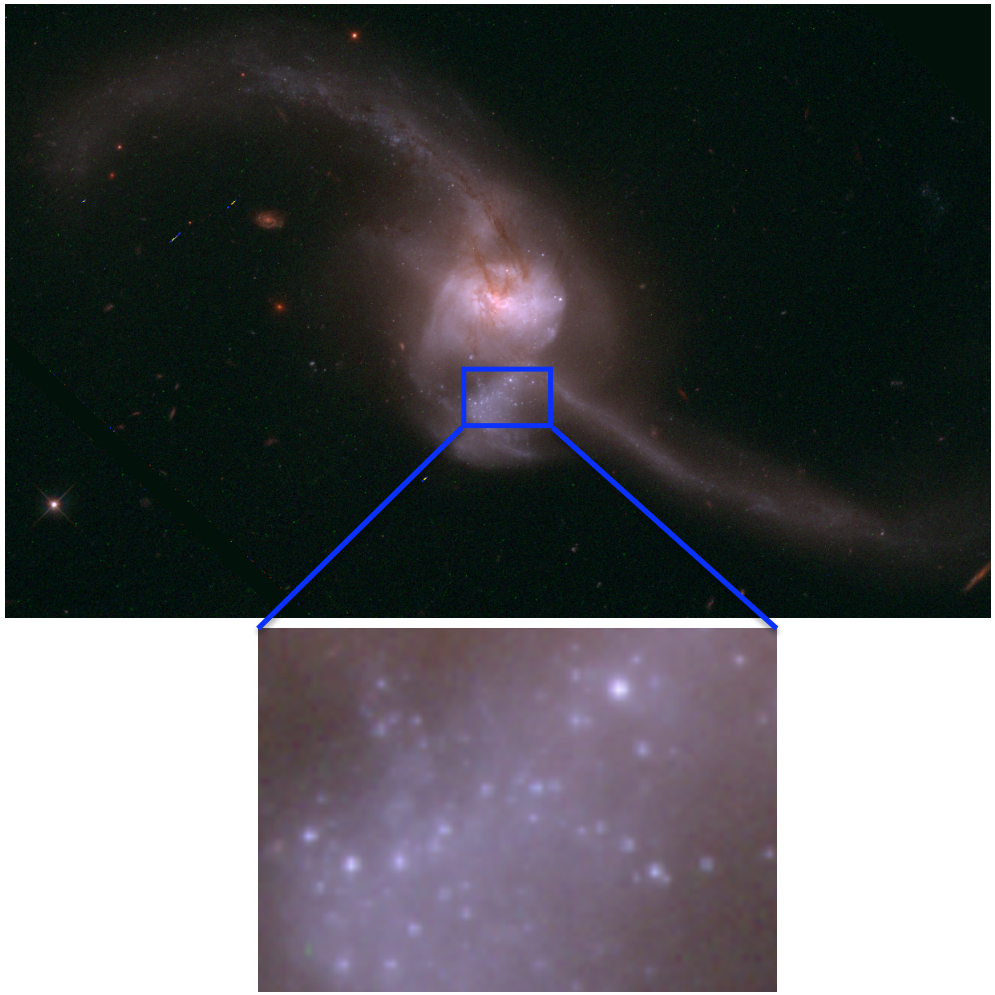
Old cluster



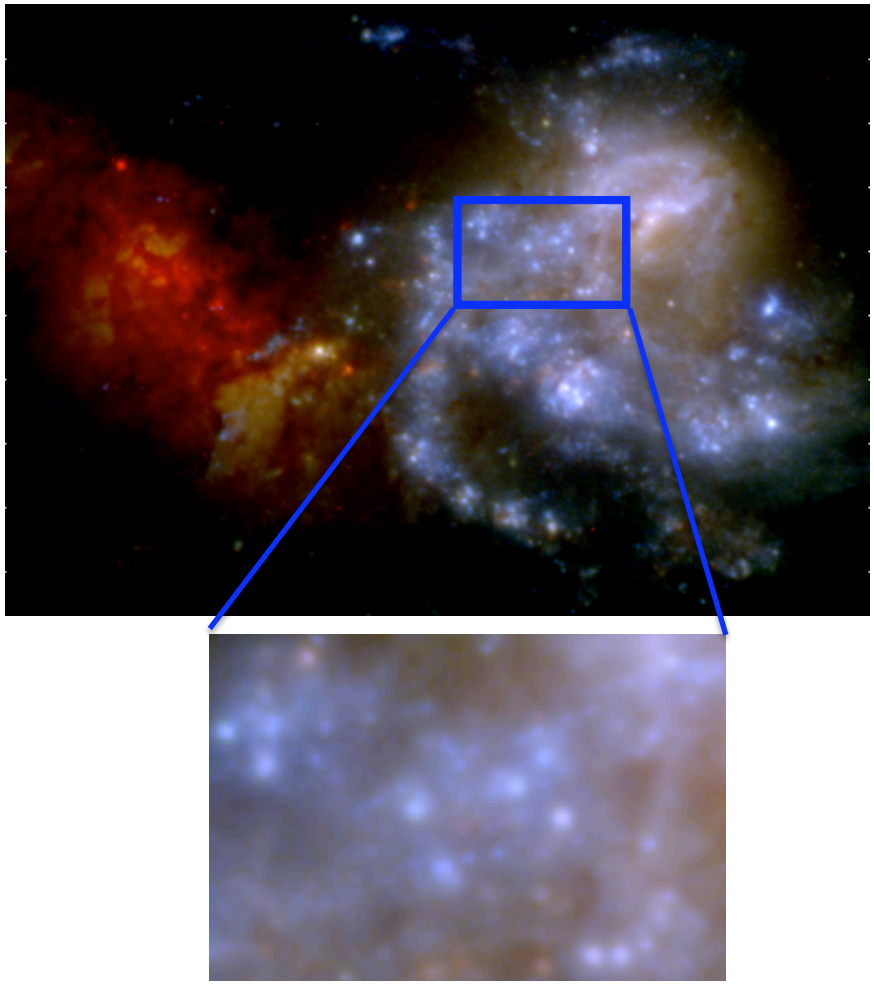
Non-resolved Populations

- Integrated light of clusters: colours, SED, spectra

NGC 2623

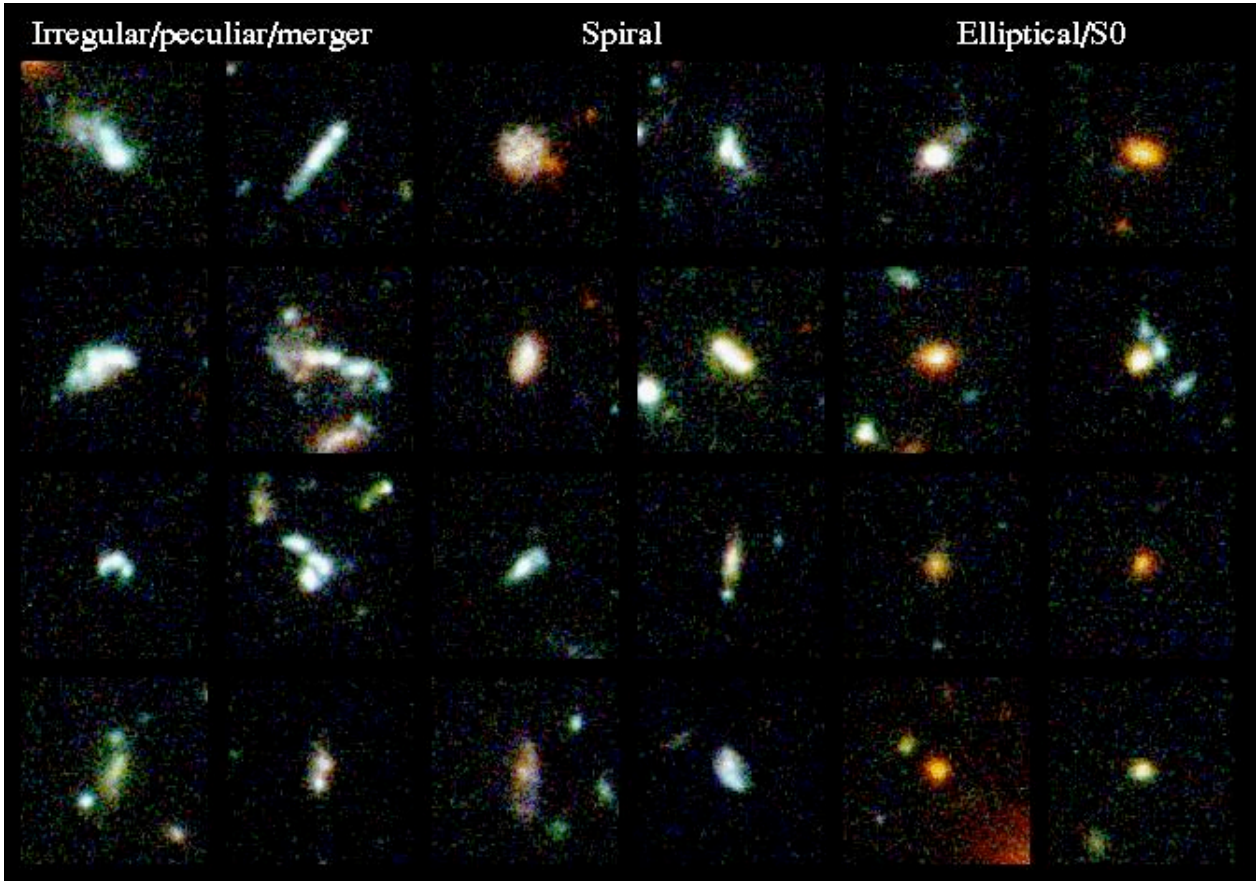


IC 1623



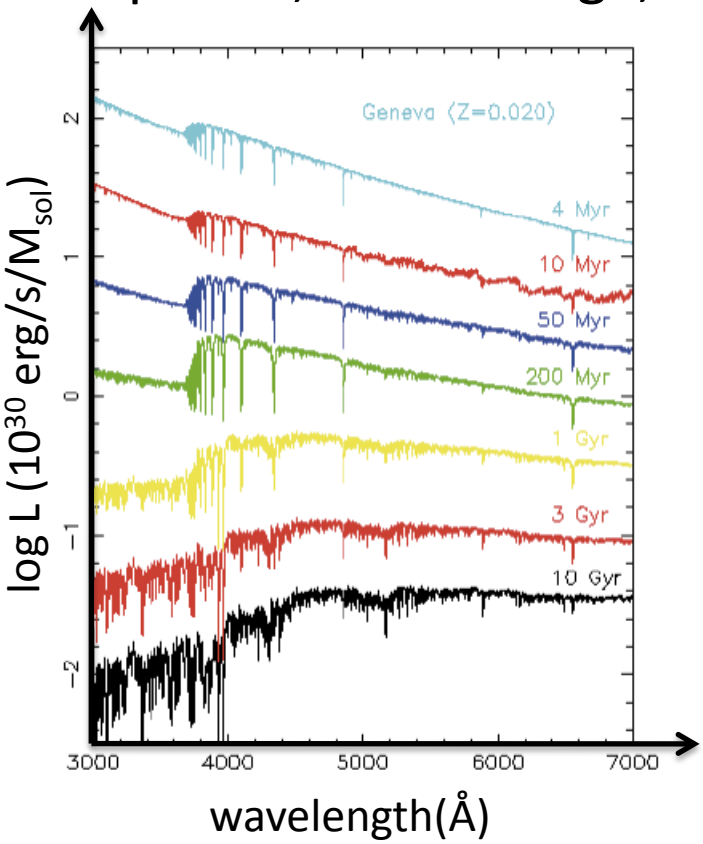
Non-resolved Populations

- Galaxies formed by several SSPs, sometimes we only know their integrated light spectra.
- Integrated light of a galaxy: colours, SED, spectra

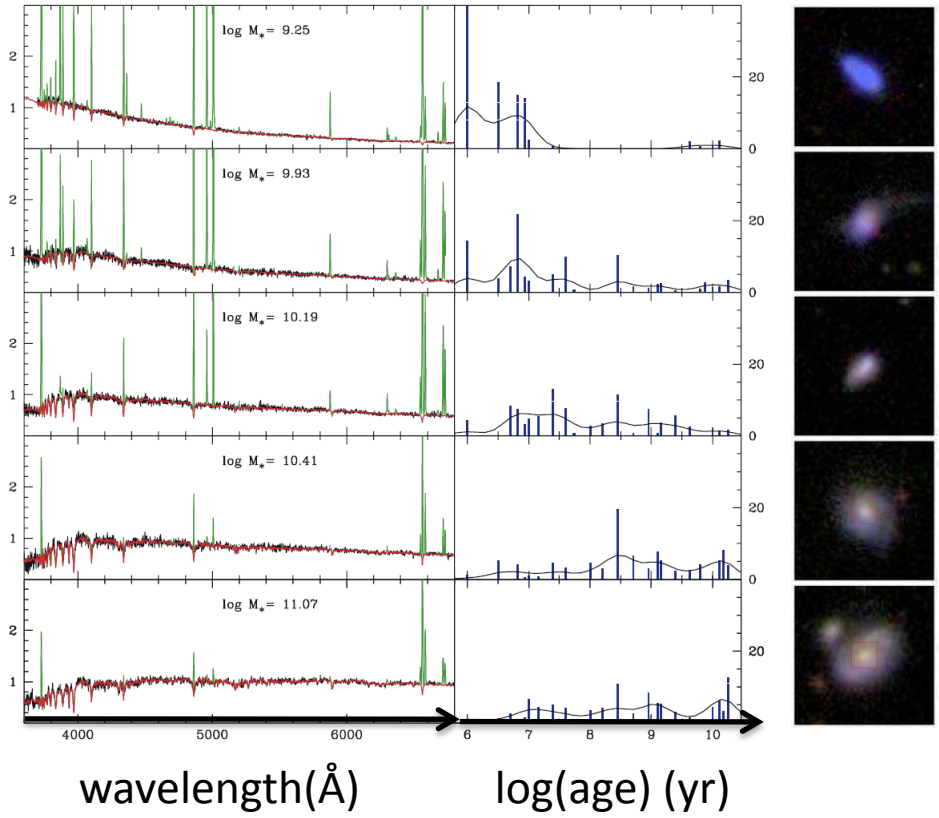


Stellar population models

- Theoretical SED of a population with t, Z
- Neccesary to derive physical properties from observations: spectra, color → age, metallicity, masses



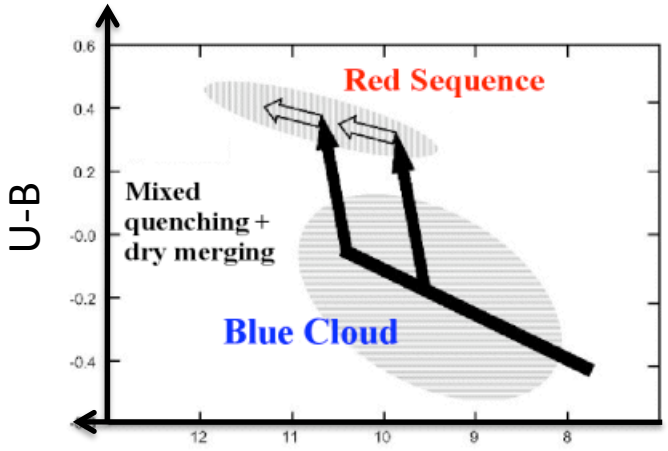
González Delgado et al. 2005



Asari, Cid Fernandes et al. 2007

SP models and galactic evolution

- Evolution imprinted in stellar populations
- Models allow us to know when galaxies have formed and evolved
- The better the models the better the knowledge



Log stellar mass, M_{sol}

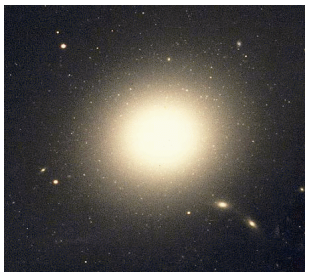
Faber et al. 2007

LATE TYPE

Low-mass
Blue
Young

¿?

EARLY TYPE

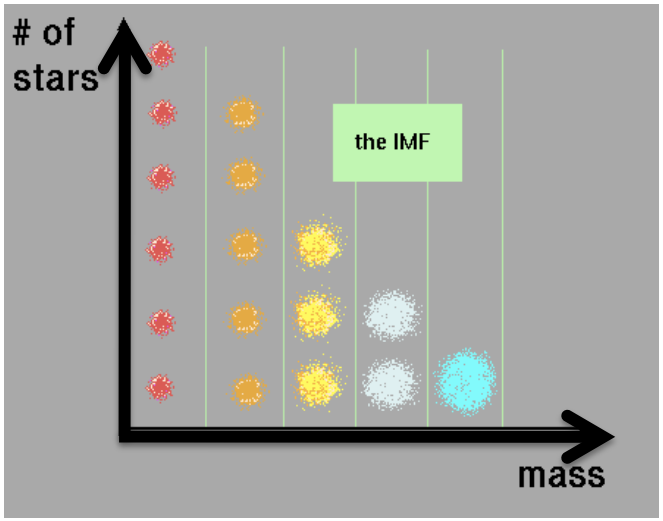


Massive
Red
Old

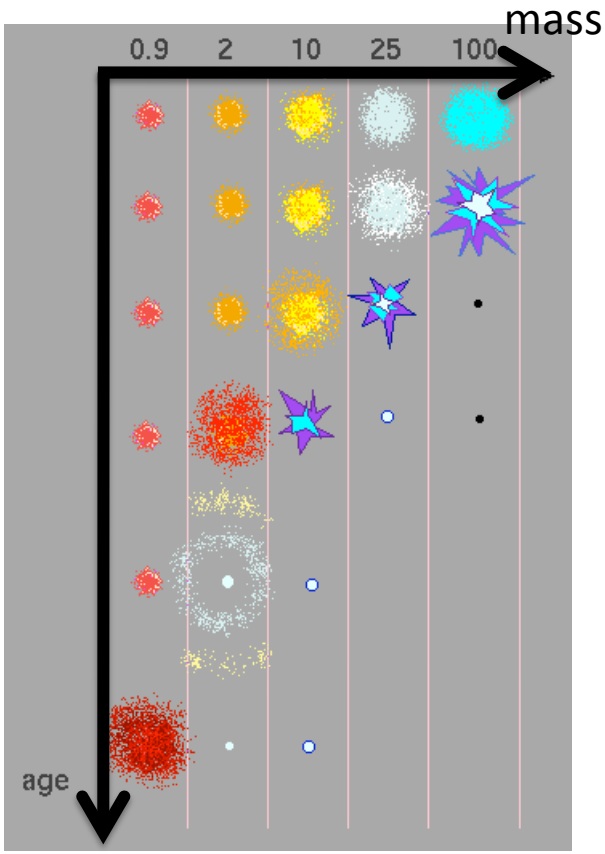
Models. Ingredients

- 3 ingredients:

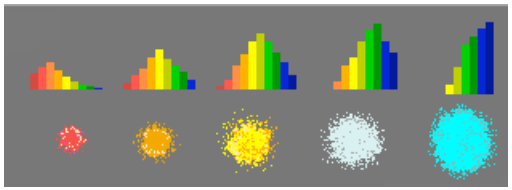
IMF

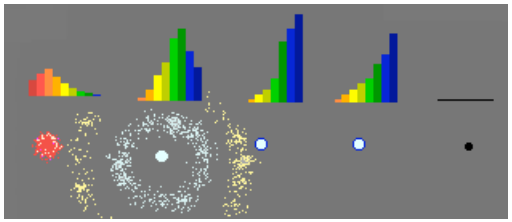


Stellar tracks



Stellar libraries

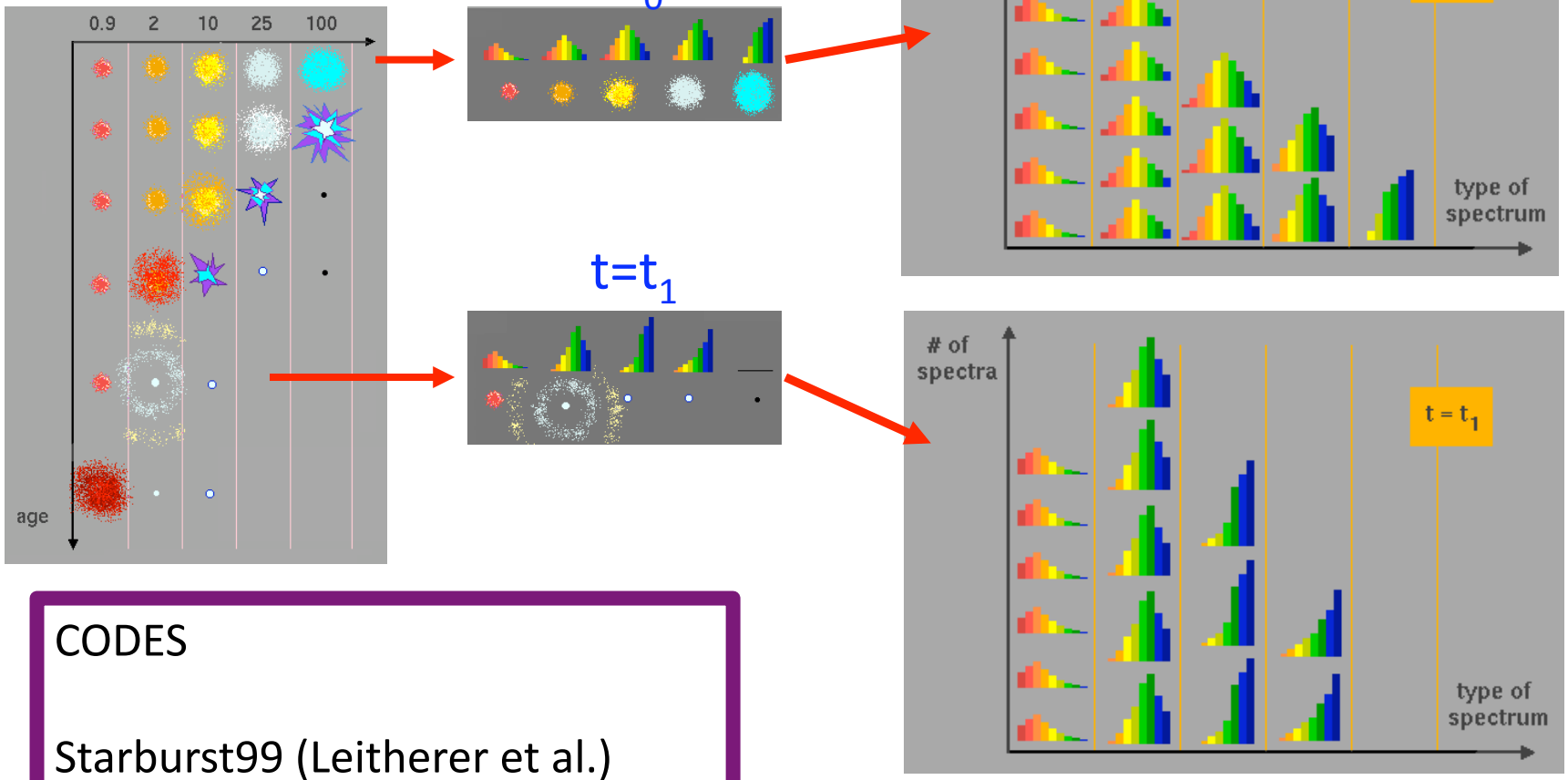




Luridiana & Cerviño

http://ov.inaoep.mv

Models. Synthesis



CODES

Starburst99 (Leitherer et al.)
GALAXEV (Bruzual & Charlot)
SED (Cerviño et al.)

Luridiana & Cerviño
http://ov.inaoep.mv

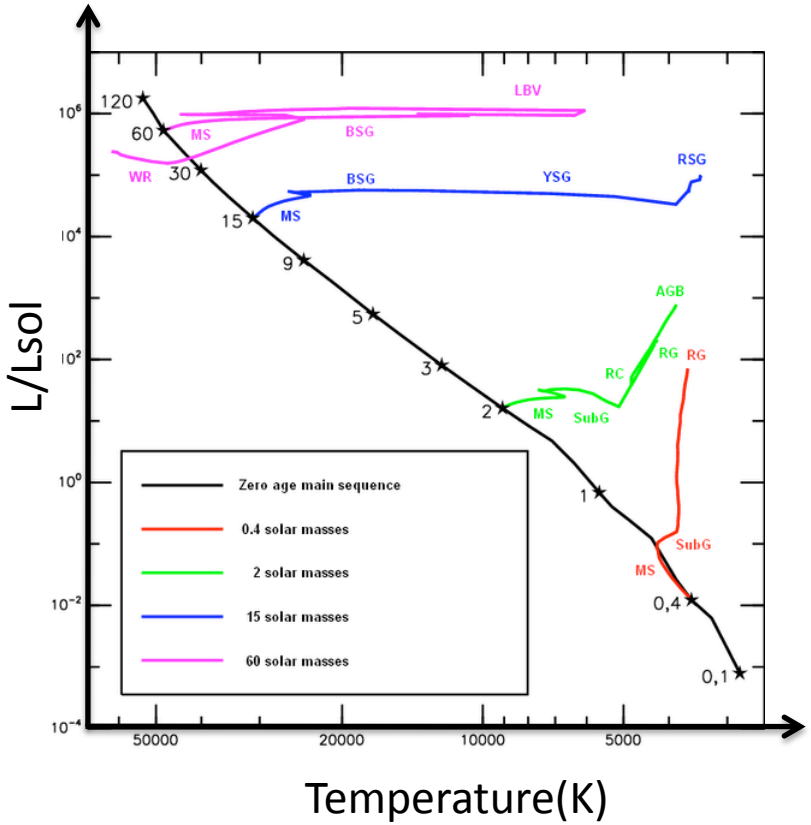
Critical ingredients. IMF

$dN/dm=m^{-1}\ dN/d(\log m)=m^{-\alpha}$

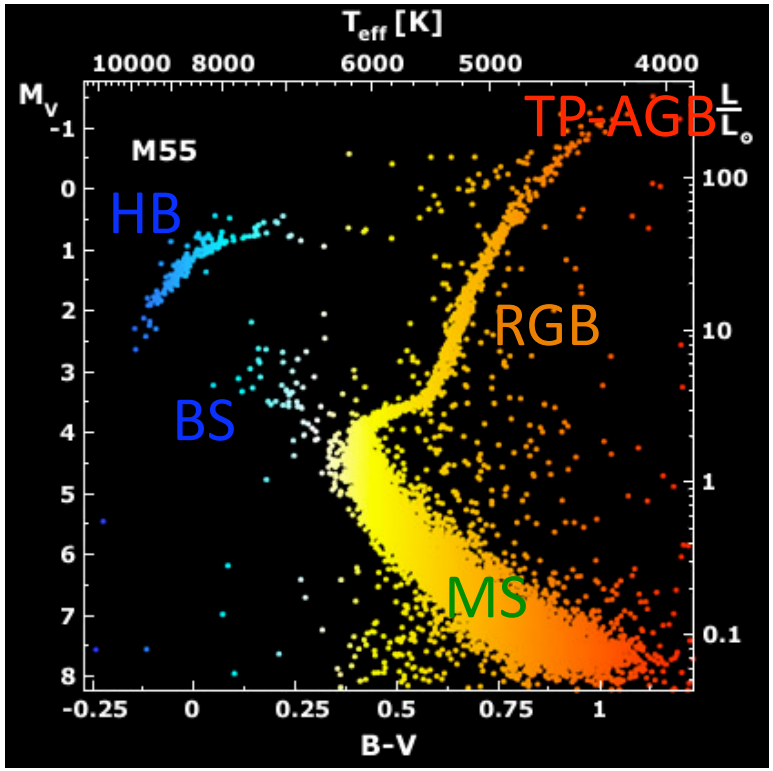
- Salpeter: $m^{-2.5}$
- Kroupa: $m^{-2.3}$ $m/m_\odot>0.5$
  $m^{-1.3}$ $0.5>m/m_\odot>0.08$
  $m^{-0.35}$ $m/m_\odot<0.08$
- Chabrier: $m^{-2.3}$ $m/m_\odot>1$
  $m^{-1}\ \exp[-(\log m - \log m_c)^2/2\sigma^2]$ $m/m_\odot<1$
- IMF impacts on:
  - Mass estimations: M/L depends on IMF
  - SFR estimations, depends on m_{up} and slope
- IMF UNIVERSALITY?? Bastian et al. 2010

Critical ingredients: Stellar tracks

- Geneva
- Padova

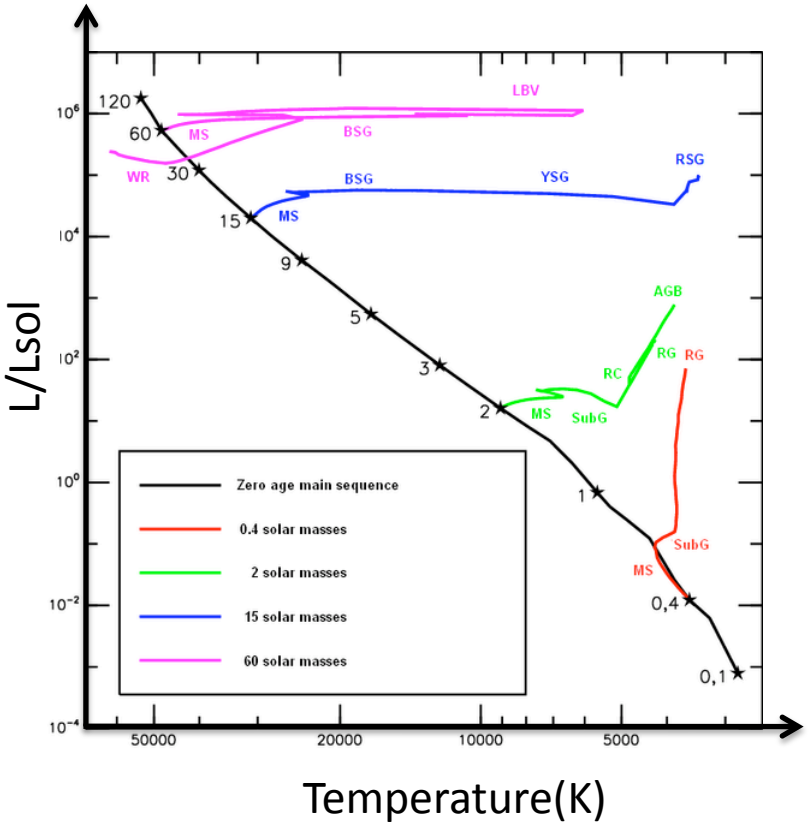


- Critical phases
  - Thermal Pulsating AGB
  - Horizontal Branch stars
  - Massive stars (WR phase)



Critical ingredients: Stellar tracks

- Geneva
- Padova



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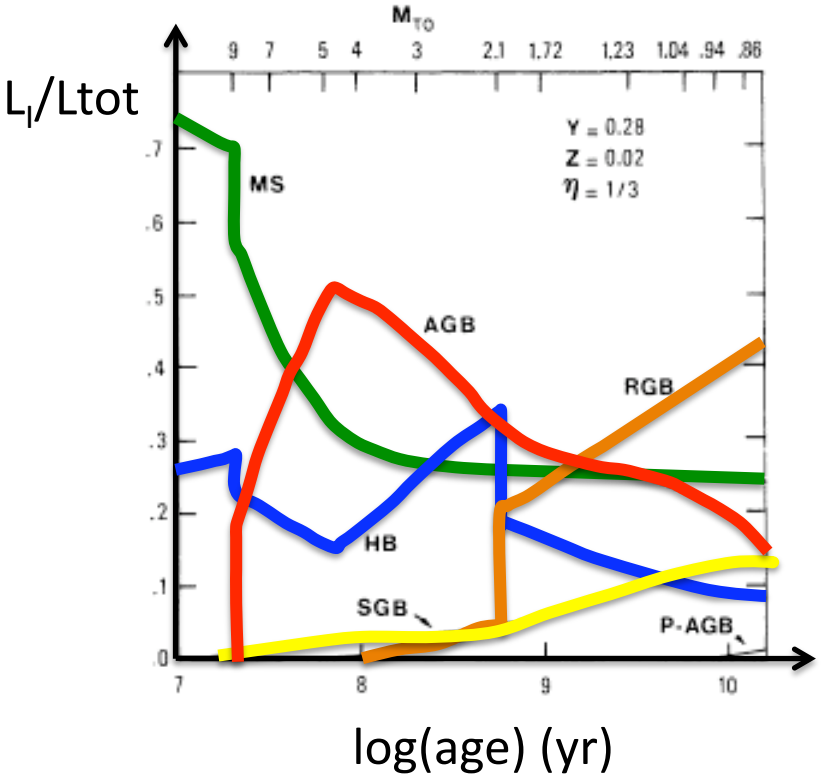
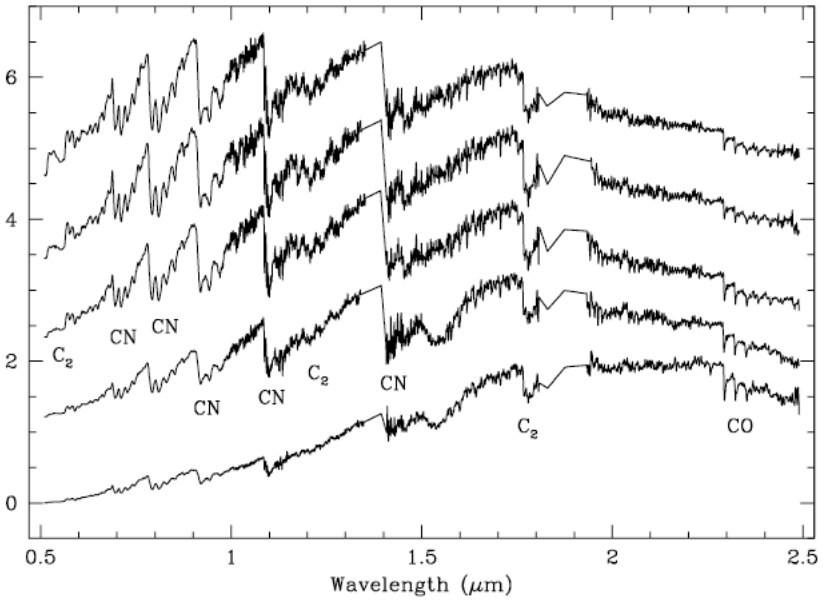


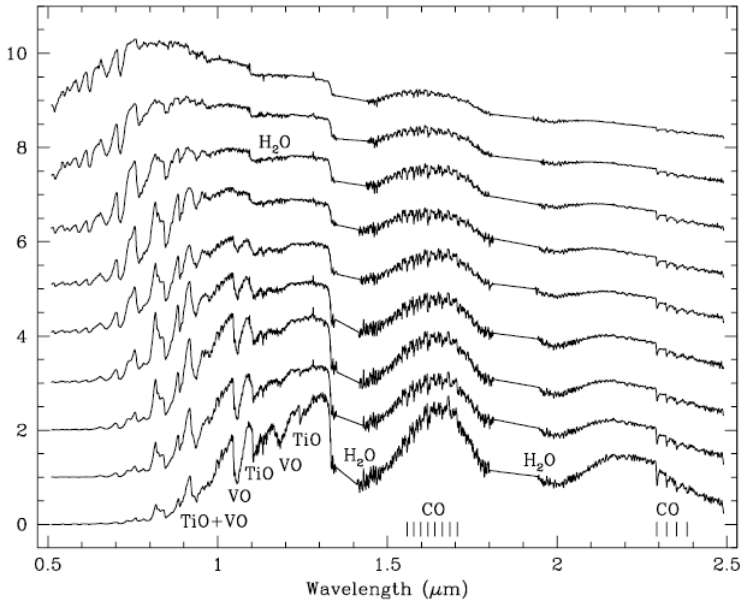
TP-AGB

- Difficult phase to modelate: variability and short-lived
- Dredge up from core to surface. Oxigen rich and Carbon rich

Carbon rich



Oxigen rich

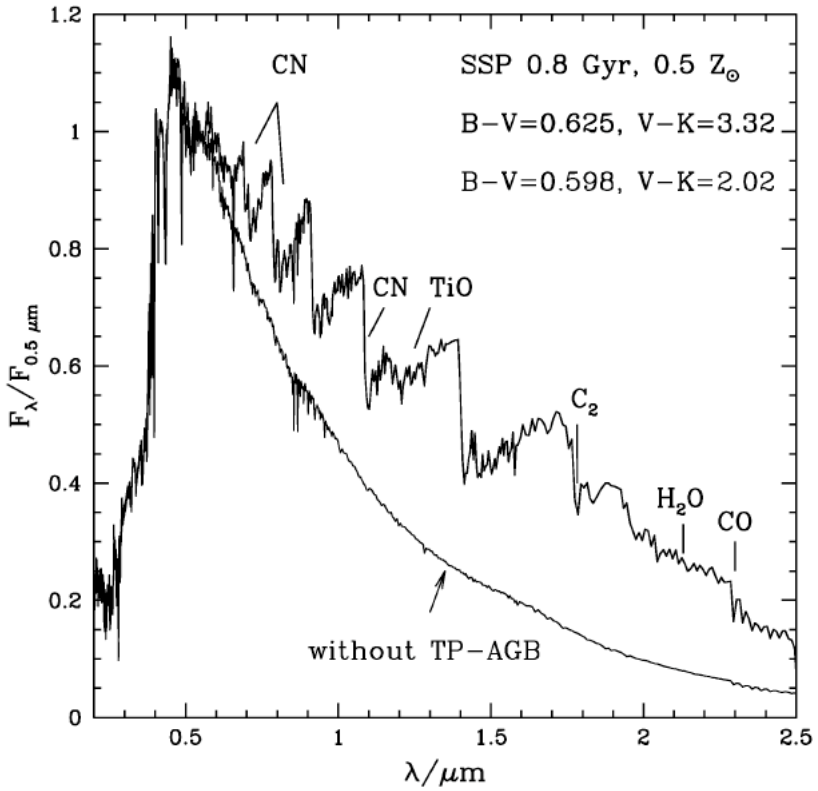


Lançon et al. 2002

TP-AGB

- Impacts on:
  - Ages determination between 100 Myr and 1 Gyr
  - Masses → K band good indicator of mass, and TP-AGB dominating in NIR

Maraston et al. 2005



Stellar libraries

- Empirical → Observations

Library	FWHM (Å)	Spectral Range (Å)	No. Stars	Commens	Liders
ELODIE	0.1	4100-6800	1388	Echelle	Prugniel & Soubiran 2004 PEGASE (Le Borgne et al 2005)
STEBLIB	3.0	3200-9500	249	Flux calibrated	Le Borgne et al 2003 GALAXEV (BC03)
INDO-US	1.0	3460-9464	1273	Poor flux calibrated	Valdés et al 2004 GALAXEV (CB07)
MILES	2.3	3500-7500	985	Flux calibrated	Sánchez-Blázquez et al 2006 GALAXEV (CB07) Vazdekis et al.
HNGSL		1700-10200	Few 100	Flux calibrated	Heap & Lanz (2003) GALEXV (CB07)

- Synthetic → Stellar Atmospheres models

Models	Resolution	Spectral Range (Å)	Atmosph	Teff Log g	Metals
Rodríguez-Merino et al 2005	50000	850-4700	Kurucz	3000-50000 Log g= 0--5	[M/H]= -2.0, -1.5, -0.5, 0.0, 0.3, 0.5
Peterson et al 2005	330000	2280-3160	Kurucz	Specific Teff and log g	1/100 to solar
Munari et al 2005	20000 2000	2500-10500	Kurucz	3500-47500 K log g= 0--5	-2.5<[M/H]<0.5 [α/Fe]=0.0, 0.4
Coelho et al 2005	High	3000-18000	Kurucz	3500- 7000 K log g= 0--5	[M/H]= -2.5, -2.0, -1.5, -1.0,-0.5, 0.0, 0.2, 0.5 [α/Fe]=0.0, 0.4
Martins et al 2005 González-Delgado et al 2005	0.3 Å	3000-7000	TLUSTY + Kurucz +PHOENIX	3000-55000 K log g= -0.5--5	Z= 0.04, 0.02, 0.008, 0.004 and 0.001

Improvement of:

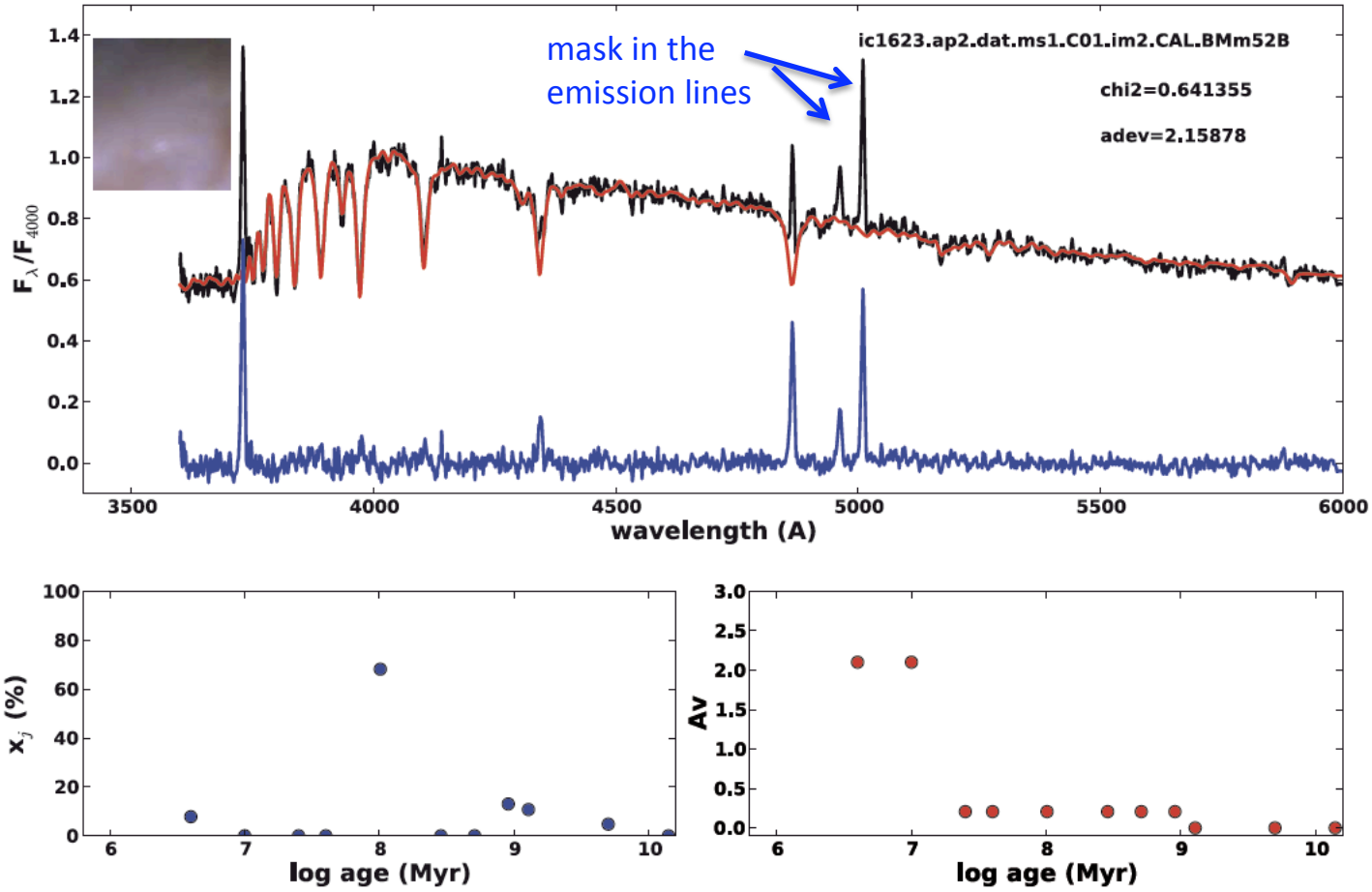
- Spectral resolution
- Spectral coverage
- Parameter space coverage (Teff, Z, g)

Methodology

- Full spectrum fitting

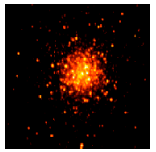
STARLIGHT CODE
Cid Fernandes et al. 2005

IC 1623



Starlight. Fossil method

- Recovers SF History of a galaxy from its spectrum

= M1  +M2  + M3  + …

$$L_{gal}(\lambda) = \Sigma_{t,Z}\ M_{SSP}(t,Z) \times SSP(\lambda,t,Z) \times e^{-\tau(\lambda)}$$

OBSERVABLES
Full spectrum

Star Formation History

SSP models

Extinction

Cid Fernandes et al. 2005

My thesis work

- Evolutive sequence:

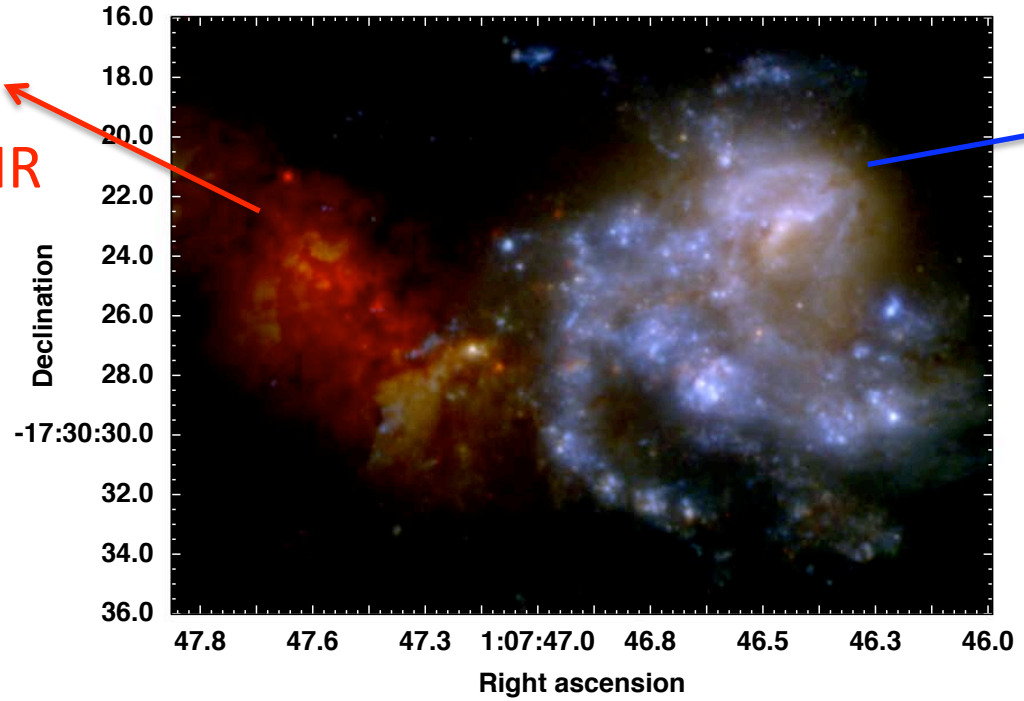
¿ (U)LIRGs→ post-Starburst QSOs → QSOs → ellipticals ?

Stellar populations ages as a clock

LIRGs: IC1623

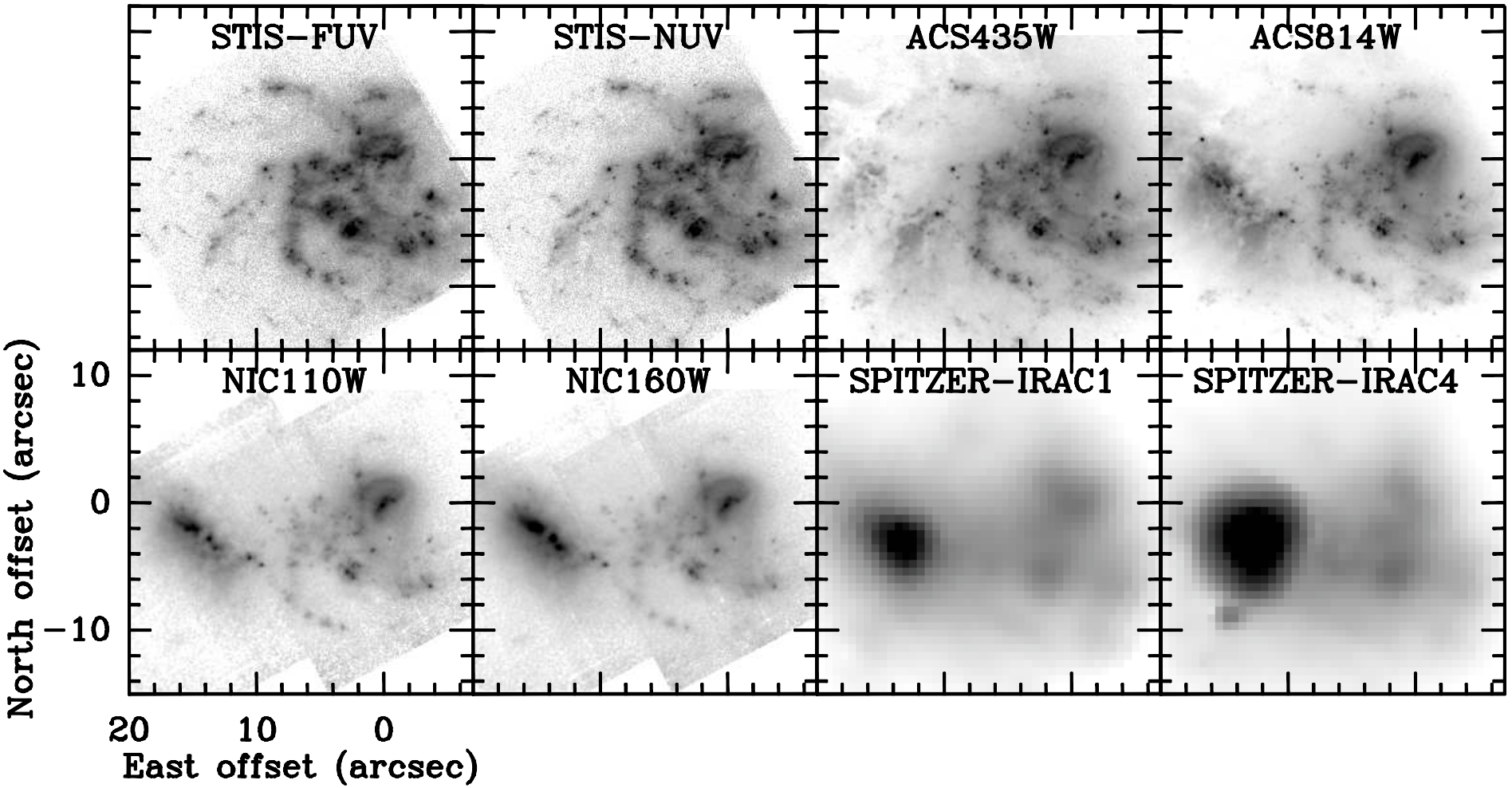
- Analysis of the stellar cluster population properties in IC1623 as it can trace the merger process and star formation history of this system.
- UV-MIR Imaging data and long-slit optical spectroscopy

IC1623 E: dominates IR

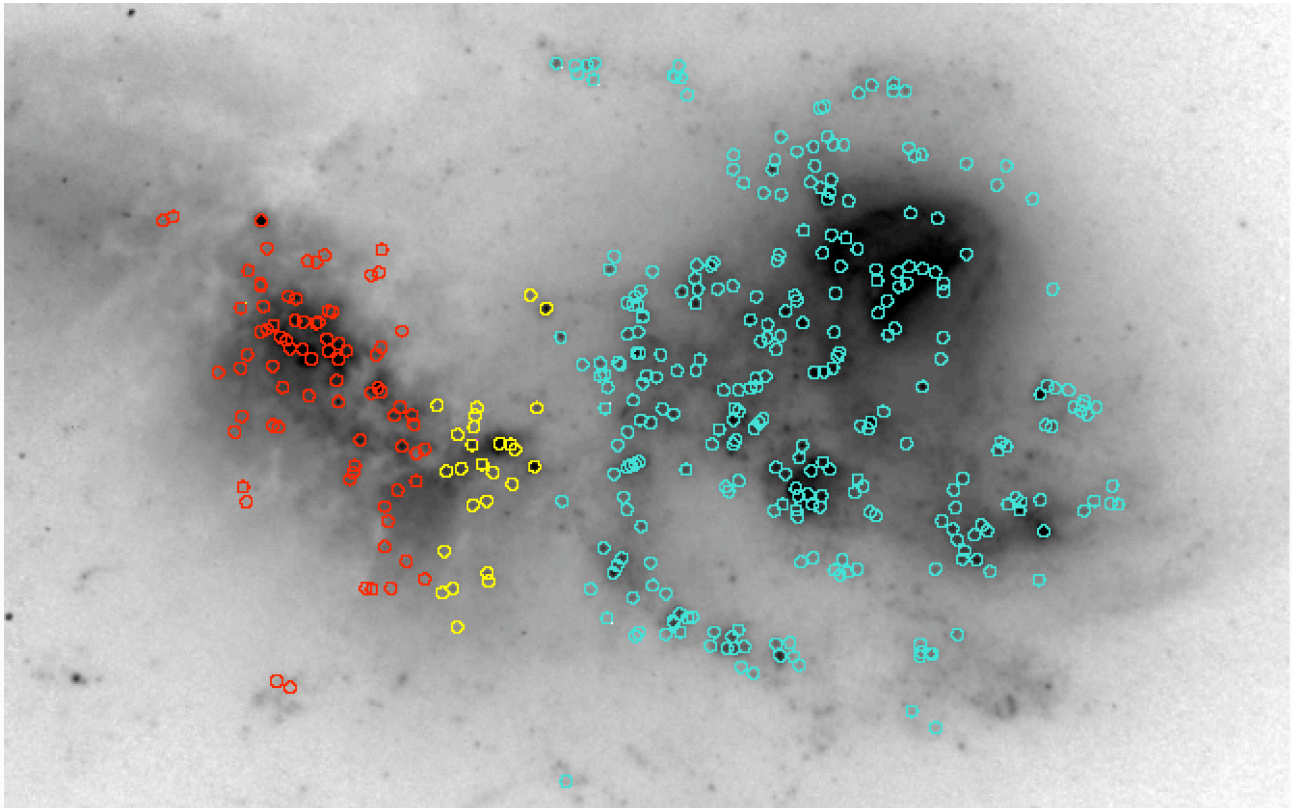


IC1623 W: dominates UV

Data. Imaging



Method. Cluster photometry



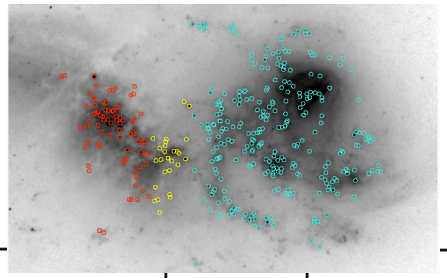
Detection: IRAF DAOPHOT.DAOFIND task

Cleaning: S/N > 40 in ACS images → 400 clusters

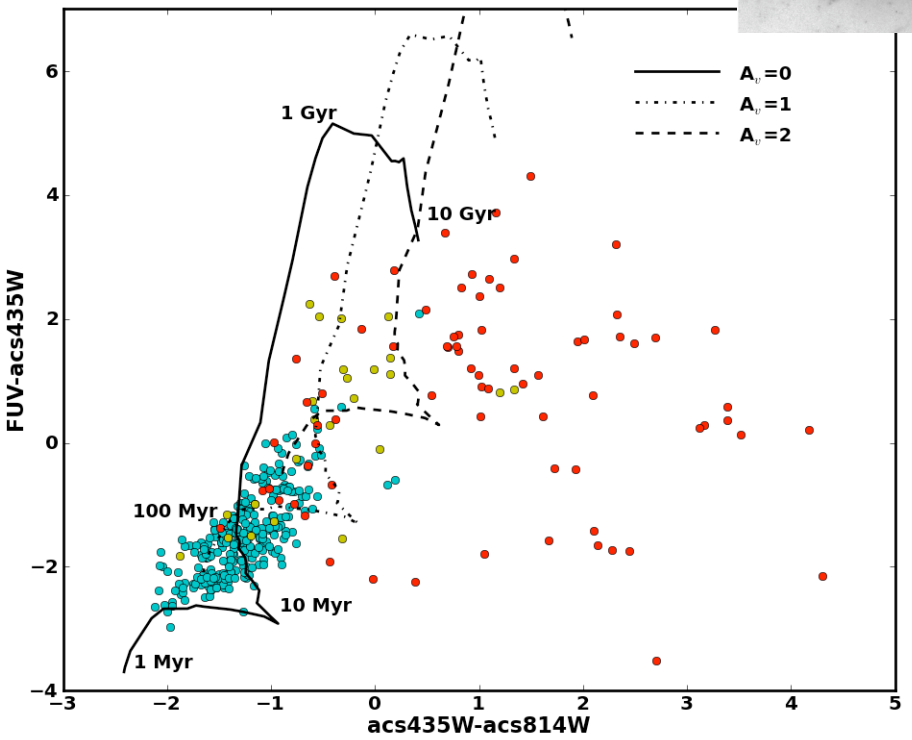
Aperture photometry: IRAF DAOPHOT.PHOT task

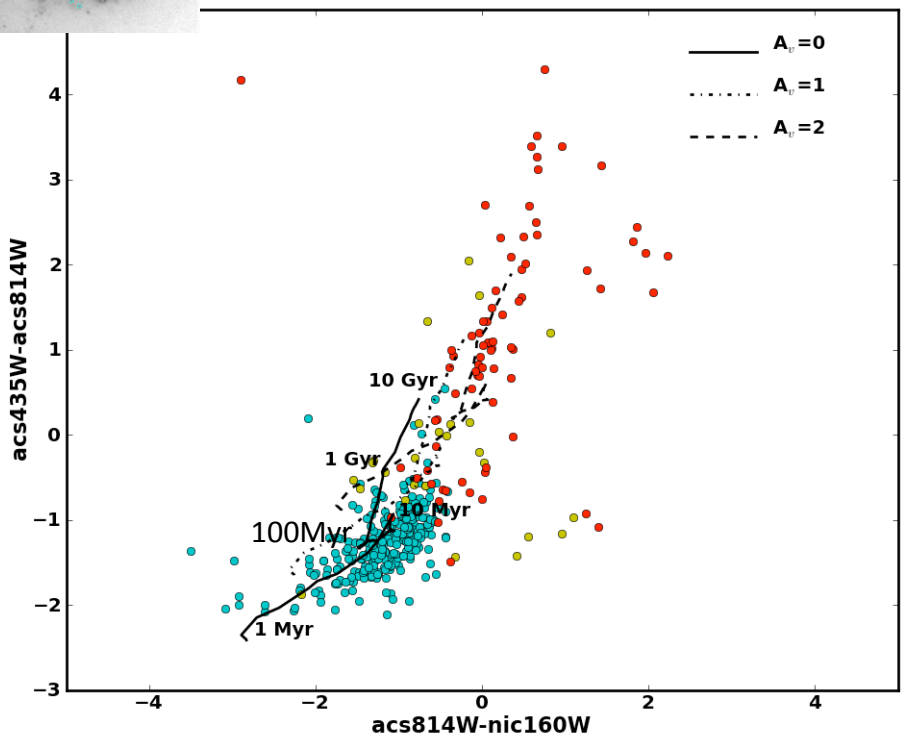
Method. Cluster photometry

FUV-Optical



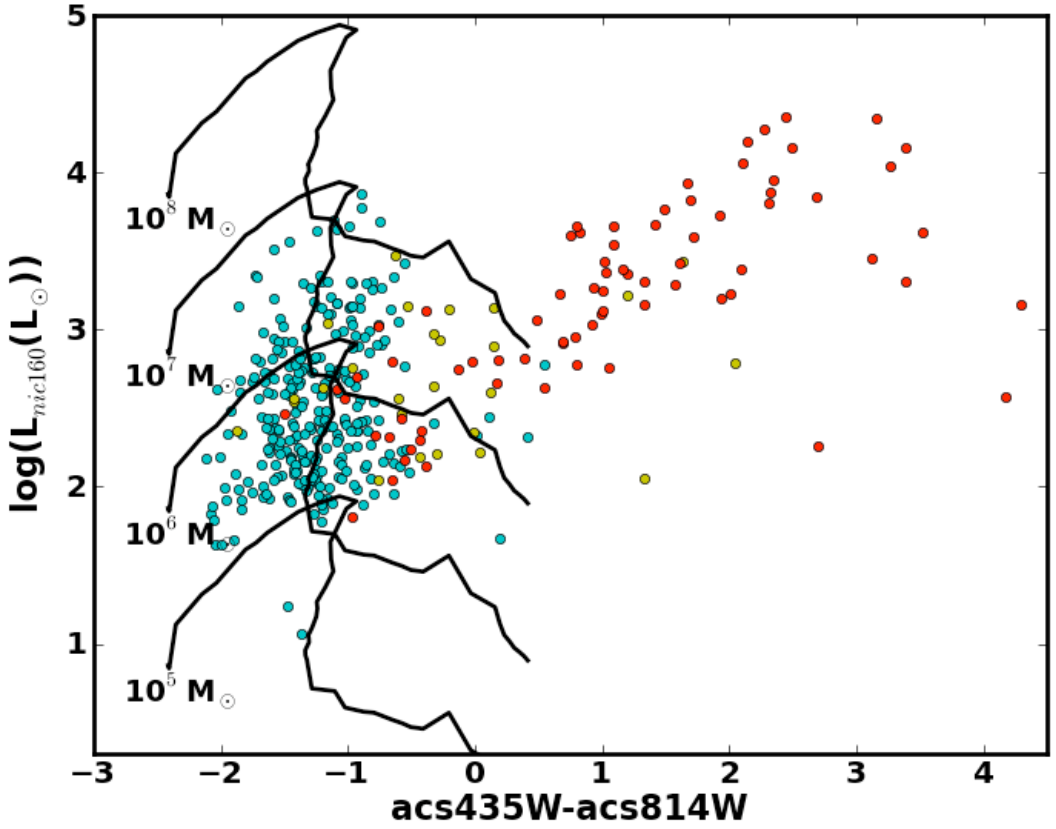
NIC160-Optical





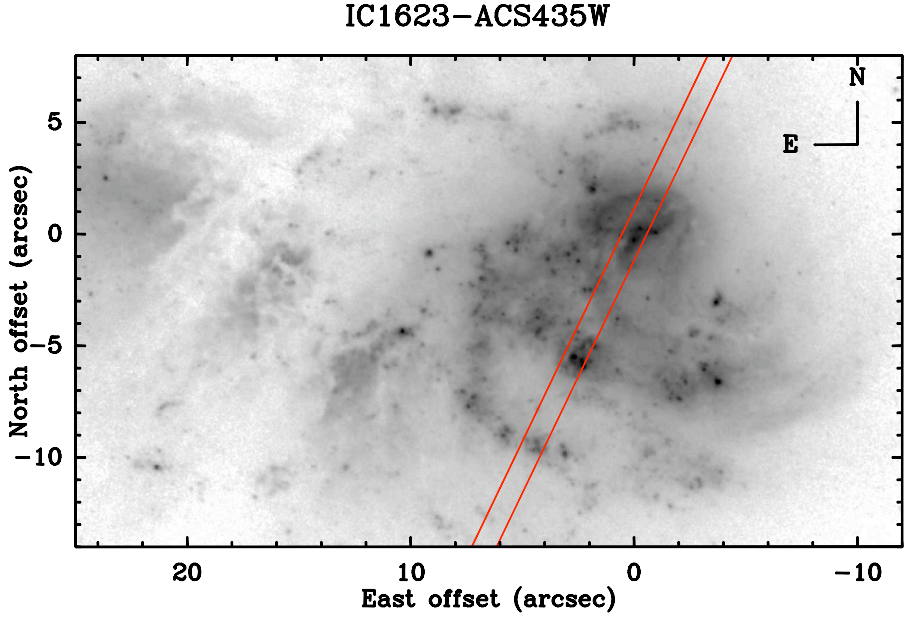
- IC 1623 W: young clusters 1-10 Myr , extinction 0-1 mag
- IC1623 E: intermediate age clusters 40 Myr- 1Gyr, extincion 2-4 mag

Method. Cluster photometry



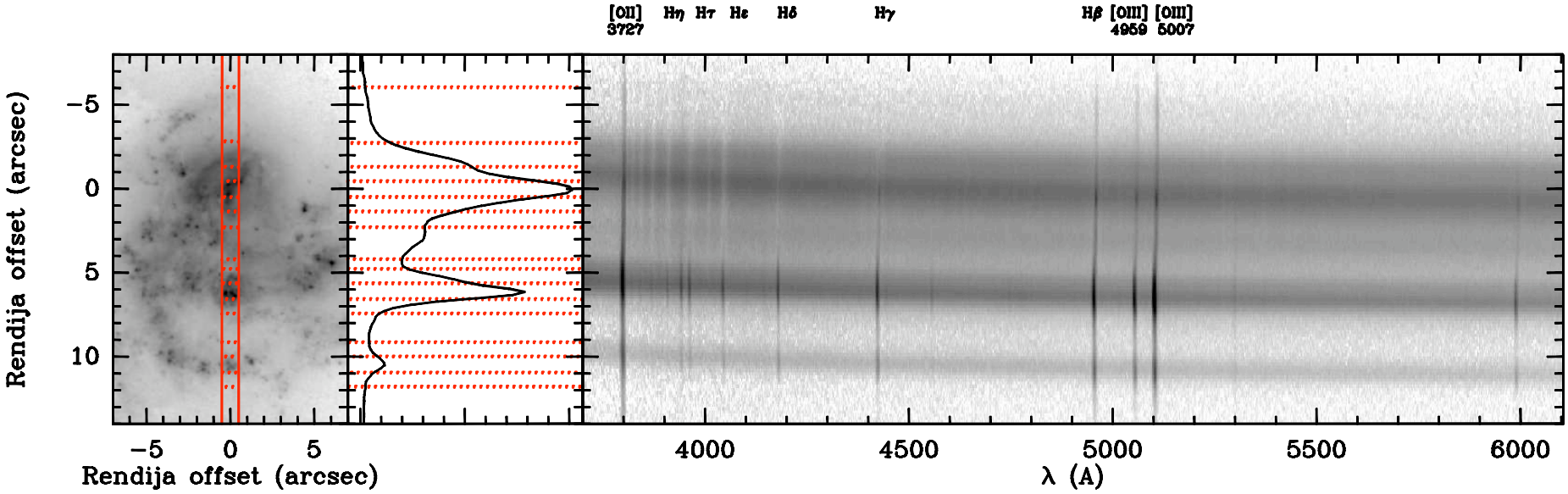
- Masses between 10^5 -10^7 $M_\odot$

Data. Long-slit spectra

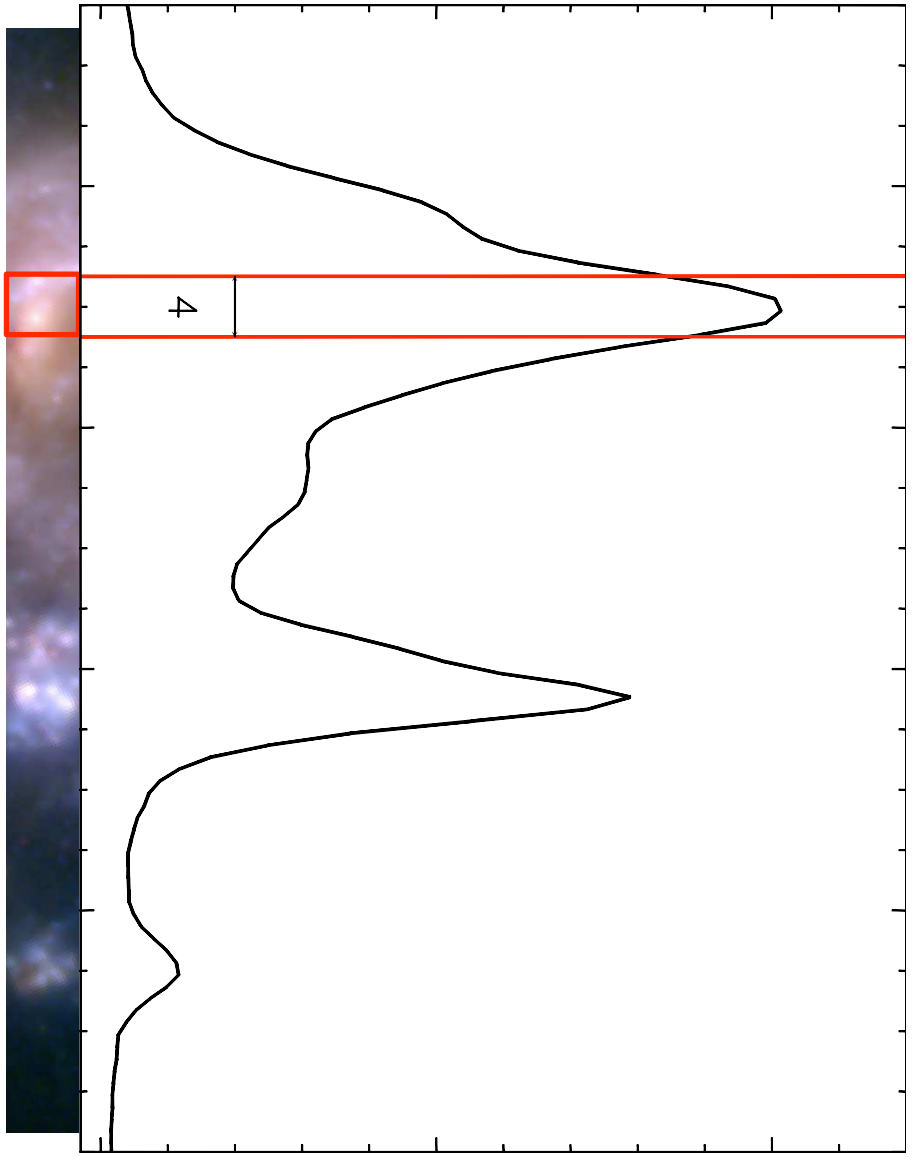


STARLIGHT SPECTRAL FITTING CODE
(Cid Fernandes et al. 2005)

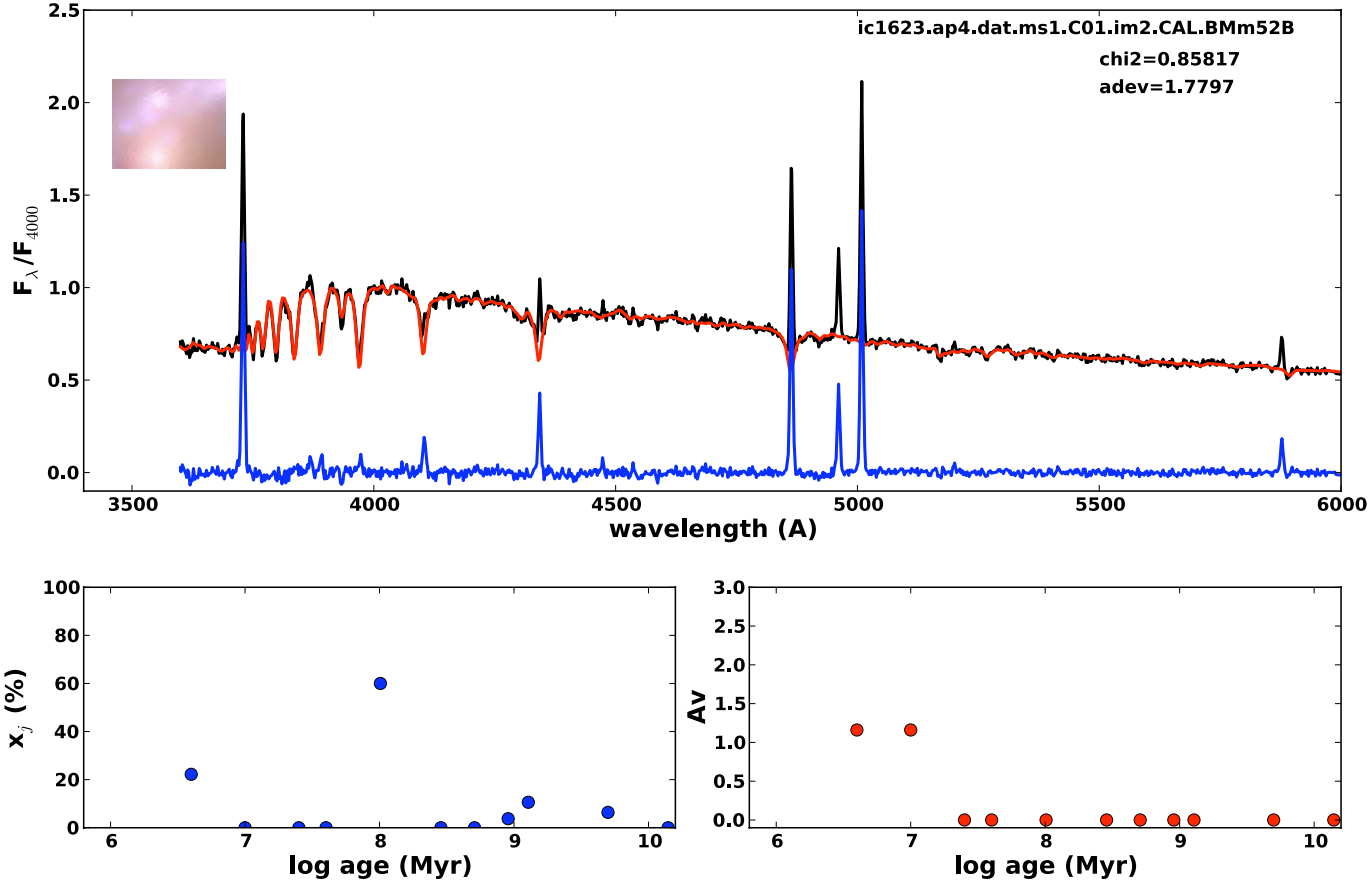
SSP Models from Charlot and Bruzual 2010:
12 Ages from 1 Myr-14 Gyr
3 Metallicities $Z_{\odot}/2$, $Z_{\odot}$, $2Z_{\odot}$



Spectral fitting. Aperture 4

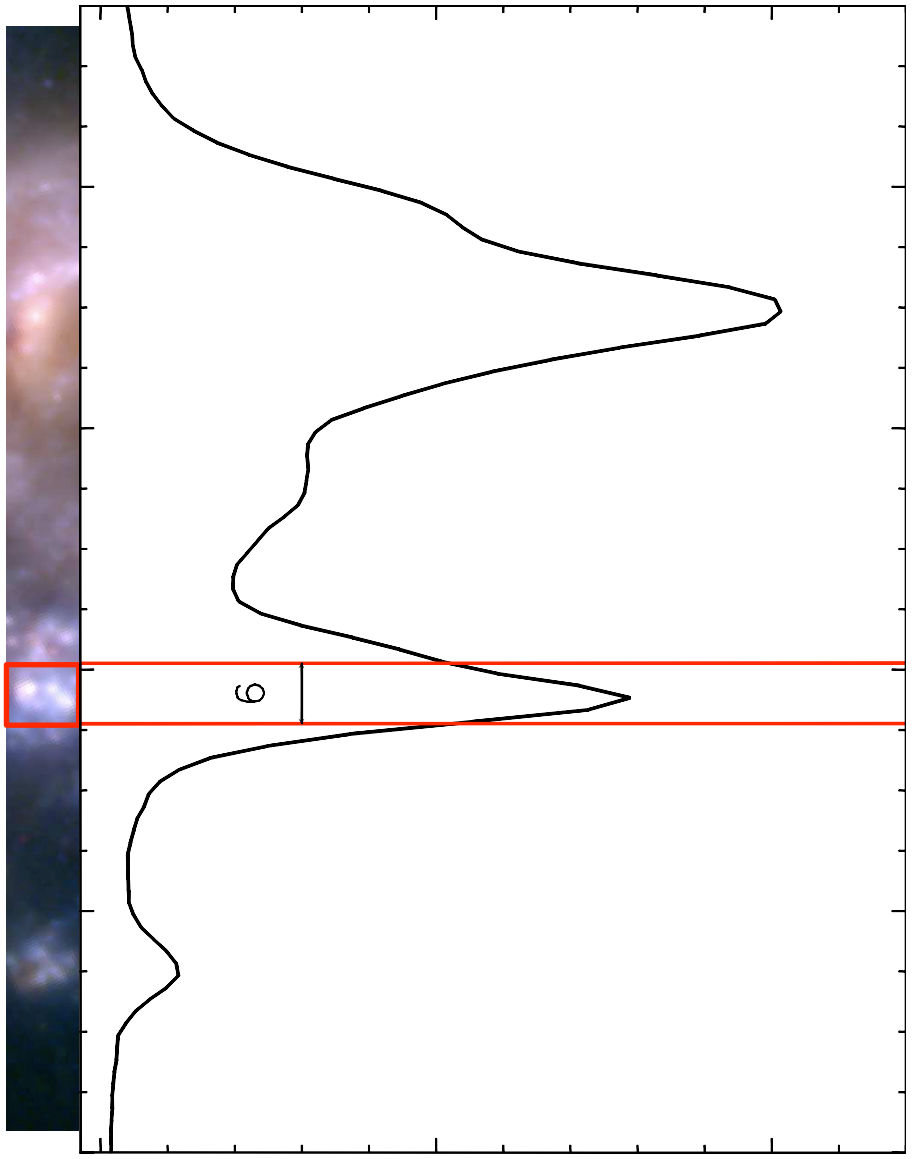


Spectral fitting. Aperture 4

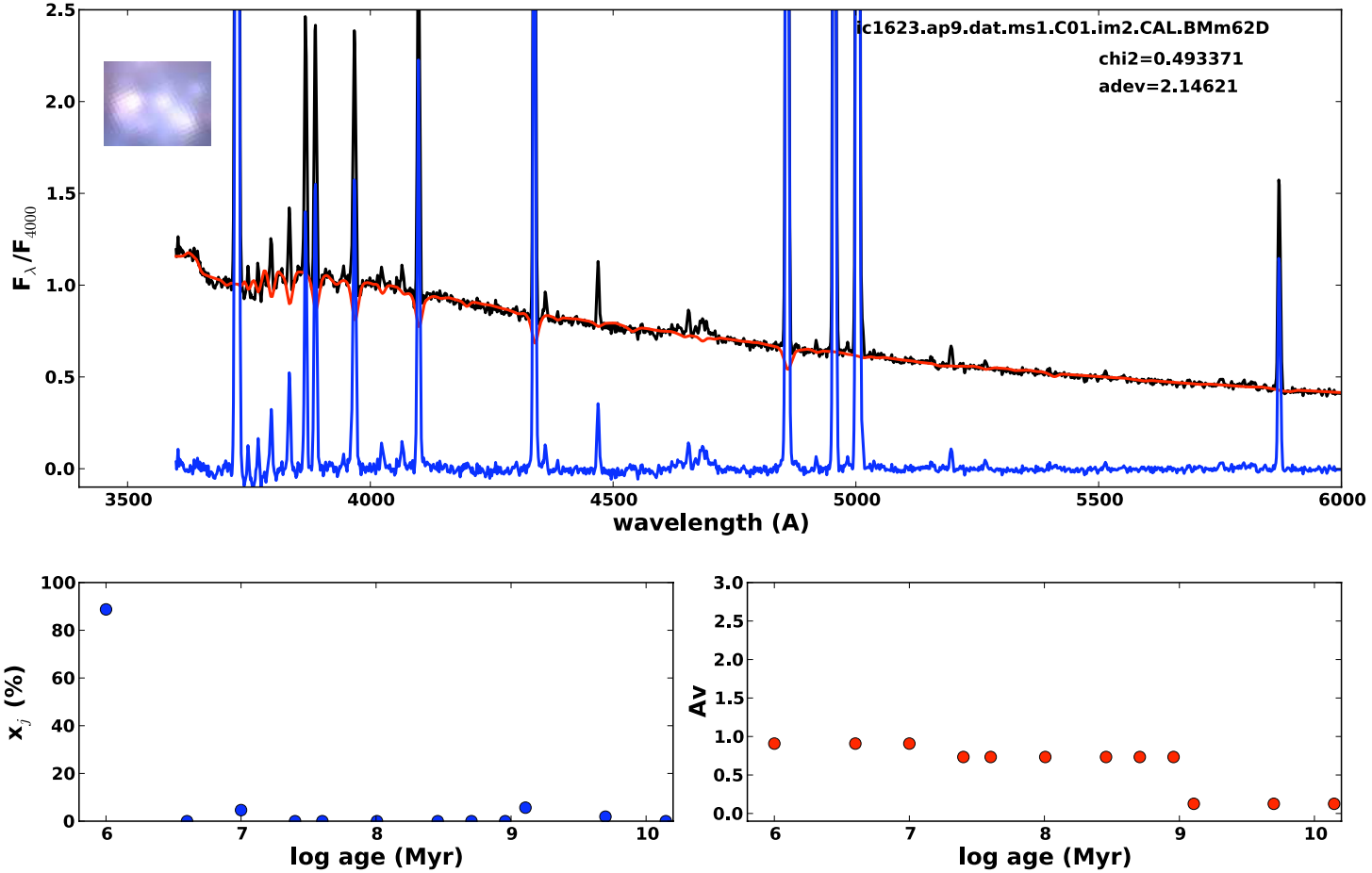


- 60%(20%) Intermediate 100 Myr(1Gyr)
  +20% very young (4 Myr)
- $Z=Z_\odot/2$
- Extinction: 0 mag intermediate / 1.2 mag very young

Spectral fitting. Aperture 9

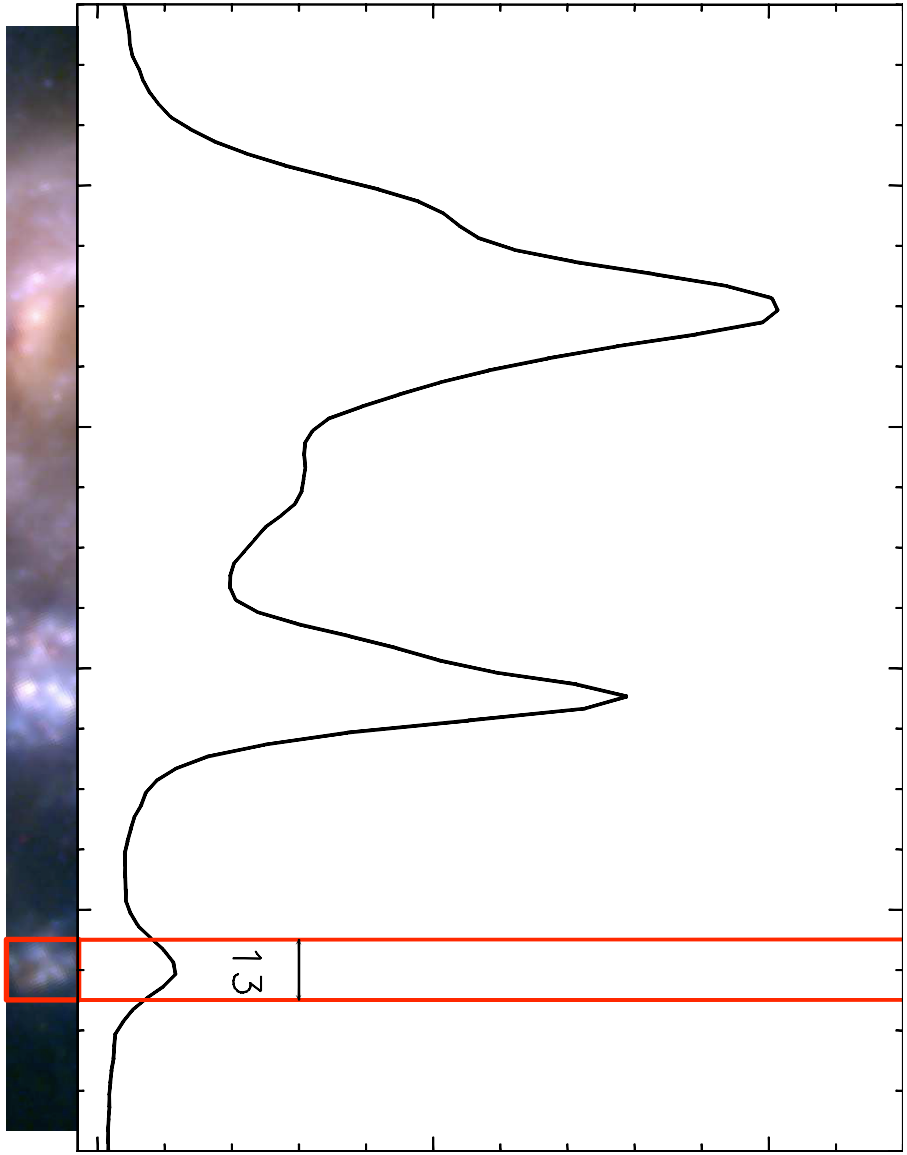


Spectral fitting. Aperture 9

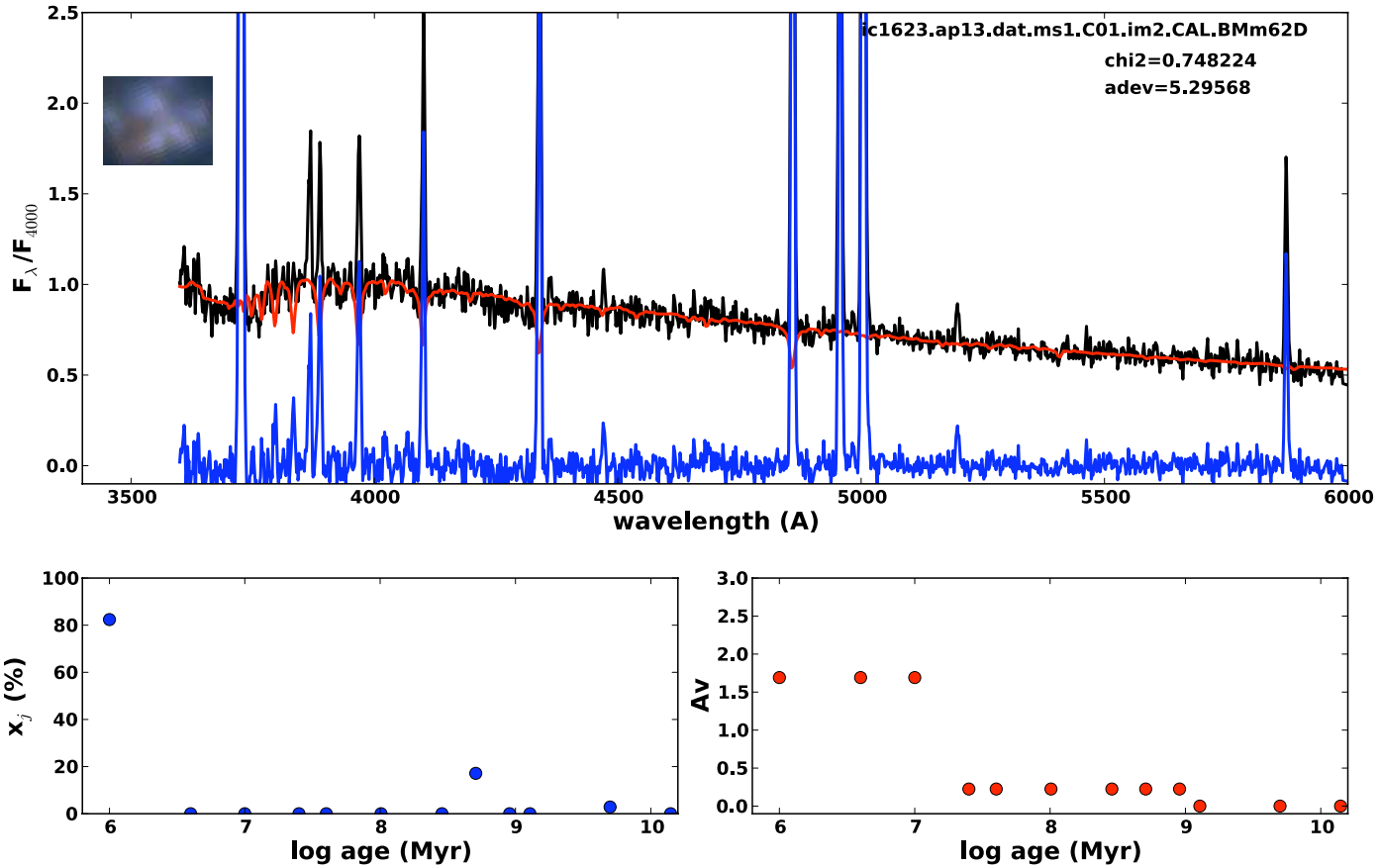


- 90%(5%) Very young 1 Myr(10Myr) +5% intermediate 1 Gyr
- $Z=Z_\odot$
- Extinction: 0.9 mag young population/ 0.7 mag intermediate

Spectral fitting. Aperture 13



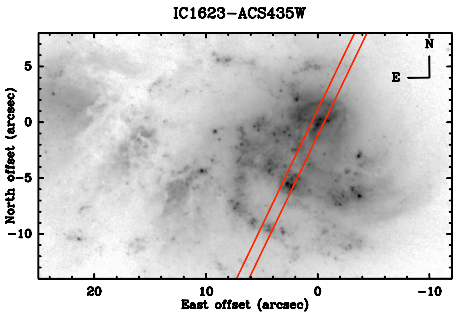
Spectral fitting. Aperture 13



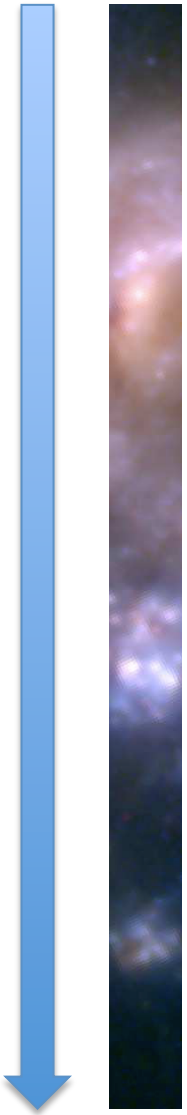
- 80% Very young 1 Myr +20% intermediate 500 Myr
- $Z=Z_\odot$
- Extinction: 1.7 mag young population/ 0.2 mag intermediate

Spectral fitting. Summary

Less contribution of young SSPs



More contribution of young SSPs



- 80-90 % Intermediate (100 Myr- 1 Gyr) + 10-20 % Young (4-10 Myr)
- A_v low 0-0.2 mag for intermediate, high 1-3mag for young
- $Z=Z_{\odot}/2$

- 80-90 % Young (1-10 Myr)+10-20% intermediate (500Myr-1Gyr)
- A_v high 0.9-1.7 mag young, medium 0.2-0.7 intermediate
- $Z=Z_{\odot}$

Summary

- PHOTOMETRY
  - IC1623W: young 1-10 Myr, low extinction 0-1mag
  - IC1623E: intermediate ages 40 Myr-1 Gyr, higher extinctions 2-4 mag
  - Cluster masses between 10^5 -10^7 $M_\odot$
- LONG-SLIT SPECTRUM (only IC 1623 W)
  - Clusters (regions 9,13) compatible with colors: young ages 1-10 Myr and extinctions 1 mag
  - Nucleus and intercluster regions (2,4,7), intermediate ages , lower extinctions
  - Ages gradient?? Older nucleus than star forming regions in spiral arms.

FIRST CONCLUSIONS

- Stellar population content in IC 1623: explained with young and intermediate populations
- Very young (1-10 Myr) clusters consistent with the SF enhanced during first encounter.


¡¡ MUCHAS GRACIAS !!