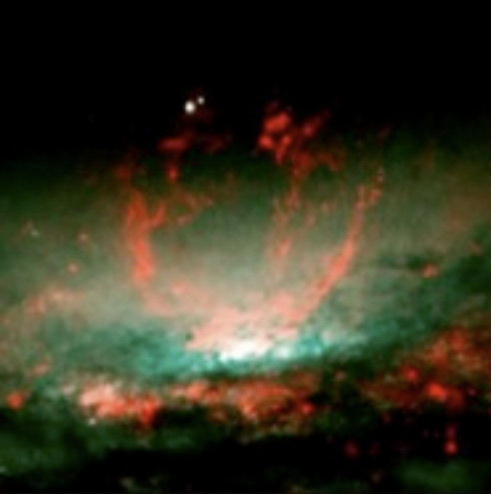
**M. Rodrigues**

*How to retrieve stellar population in starburst*

In starburst galaxies, the light emitted by massive stars dominates the photon budget along most of the spectral energy distribution: hidden by the luminous stars, the fraction of old stellar population is systematically underestimated by current methods [Wuyt et al. 2009]. This systematic has a large impact on the study of stellar populations and stellar masses in distant galaxies, when galaxies were actively forming stars. We have recently implemented a new algorithm to retrieve stellar populations from spectroscopy and photometrical data using constrains from the observed SFR. The method relies on a meta-heuristic minimization method (the swarm intelligence algorithm). It allows us to alleviate the well-know degeneracy between age and extinction, and better extract the hidden older stellar populations.



# Stellar populations in distant starburst galaxies

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CENTRA-Instituto Superior Técnico,  Portugal

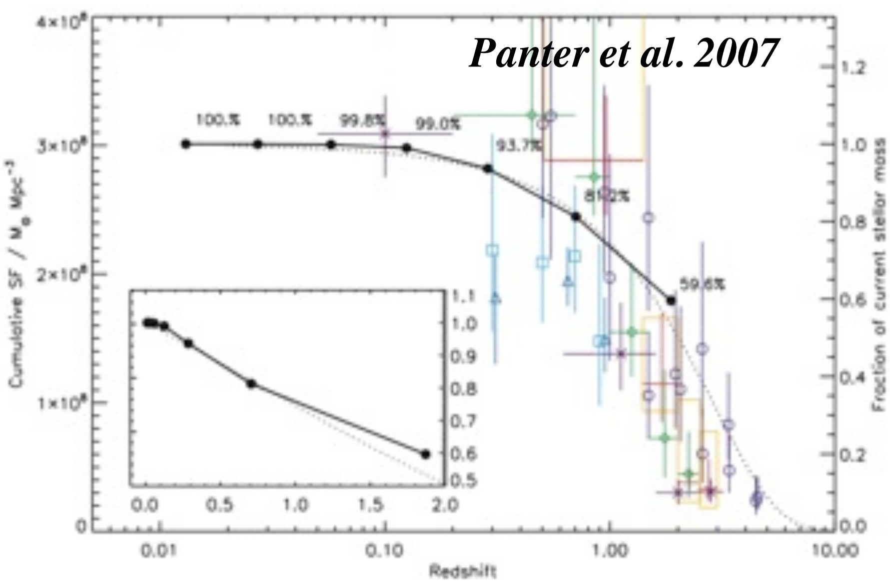
Collaborators :  F. Hammer, H. Flores, M. Puech, Y.C. Liang, I. Fuentes-Carrera, Y. Yang, R. Delgado

*Extreme Starbursts in the local universe - Granada - June 2010*

## Astro-arqueology

Retrieve the stellar population composition of galaxies

Determining the **star formation history** of galaxies provides insights into the growth of their stellar mass.




Physical process governing the assembly and evolution of galaxies (secular grow, merger events)

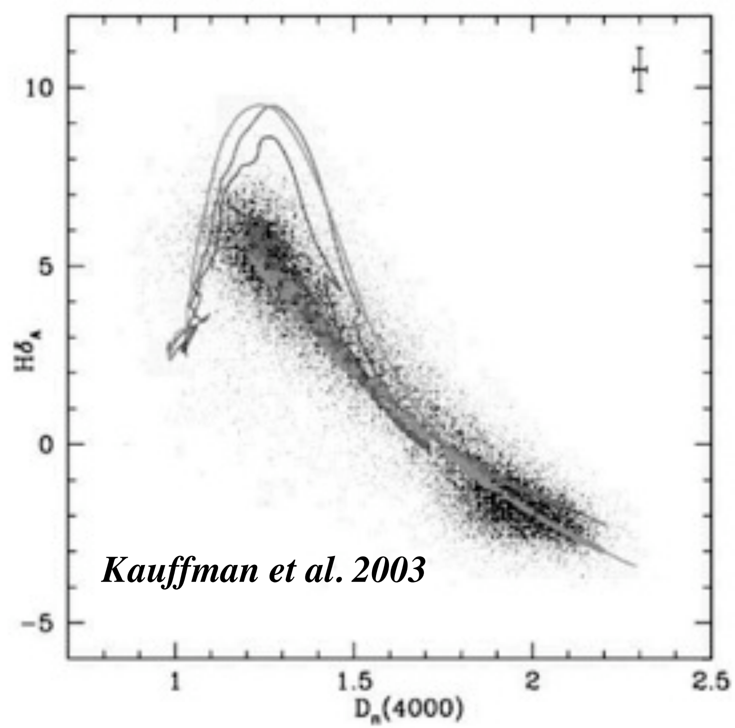
Constrain the **stellar mass** :

- One of the most fundamental properties (correlation with SFR, Metallicity, gas fraction, etc..)
- An important ingredient of the evolution of galaxies.

## From spectral features

Typical spectral features of old
and intermediate age populations

**Parameterized SFH:**
Bayesian approach - library of CSP: i.e
Kauffman et al 2003




*Mateus et al. 2006*

## From spectral features

Typical spectral features of old and intermediate age populations

**Parameterized SFH:**
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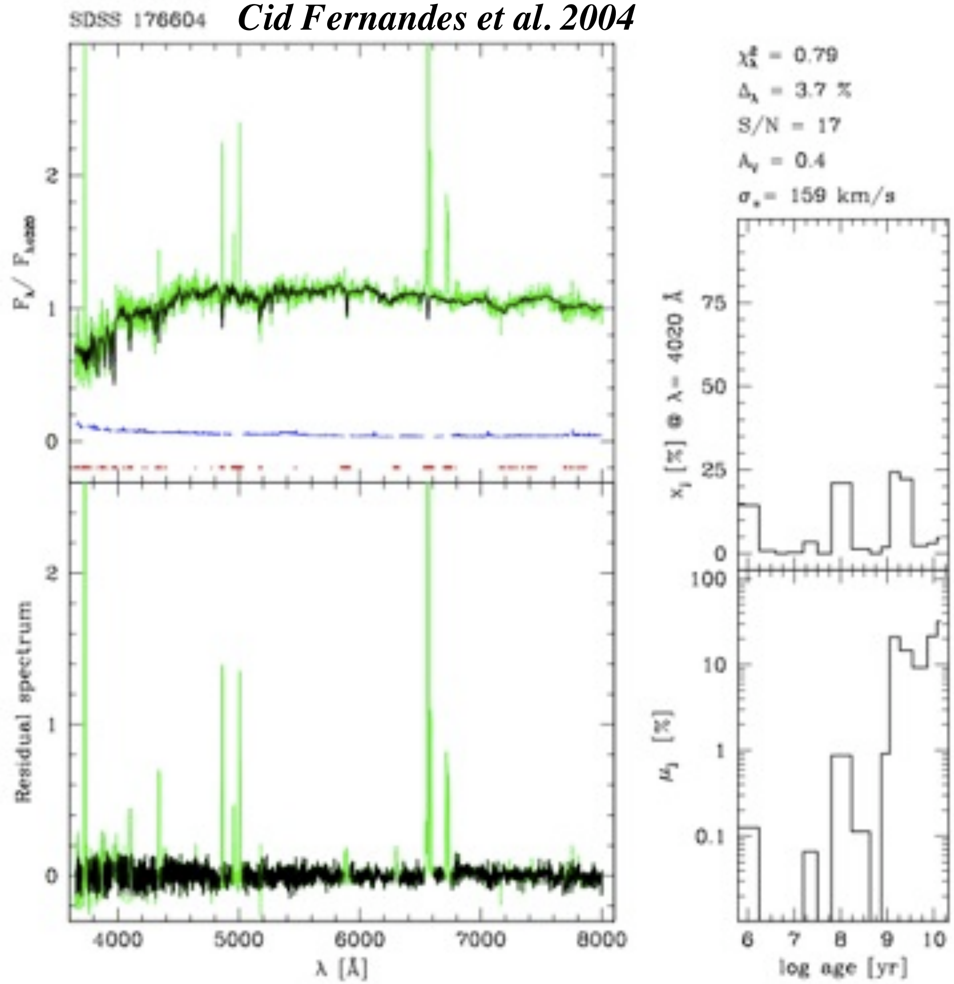
Kauffman et al 2003

**Without Prior on SFH:**
Linear combination of SSP or star cluster templates, i.e. full spectra fitting [Starlight, VESPA, MOPED, etc..]

*Cid Fernandes et al. 2004*

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Good agreement **but**

$\log M_{stars}$ (full-spectra) =+0.12 dex $\log M_{stars}$ (K03)

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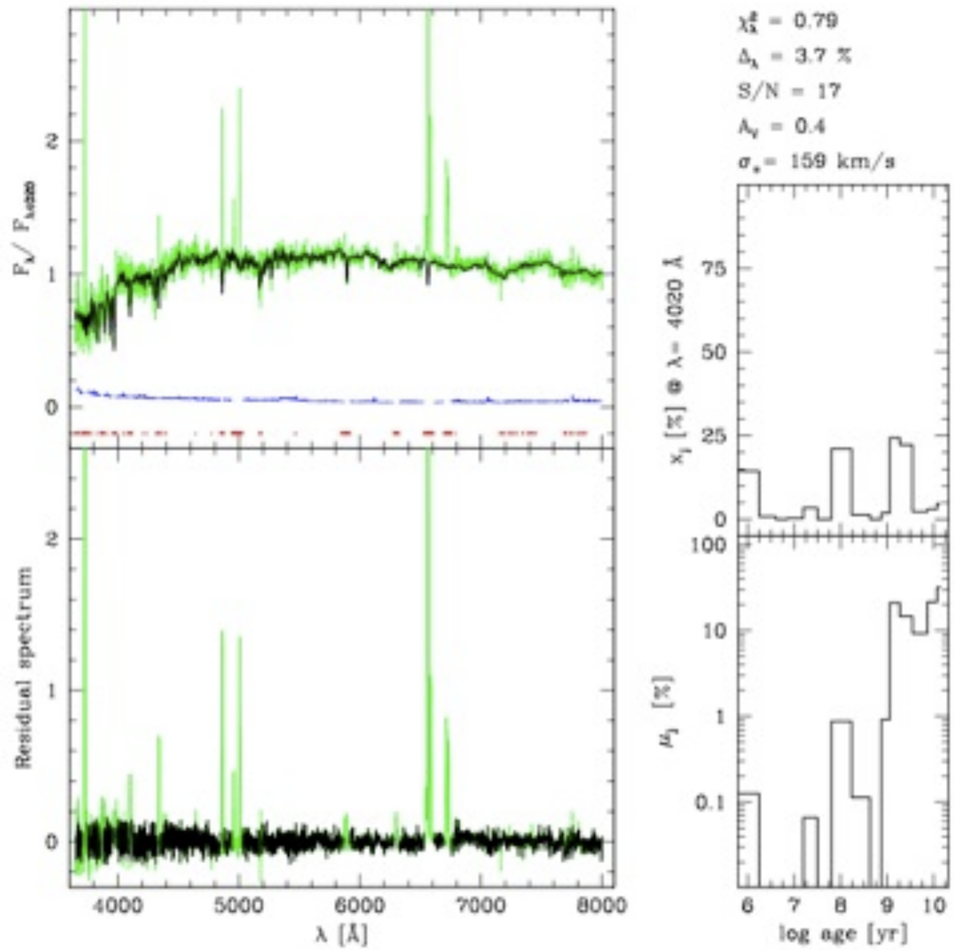


*Mateus et al. 2006*

## From spectral features

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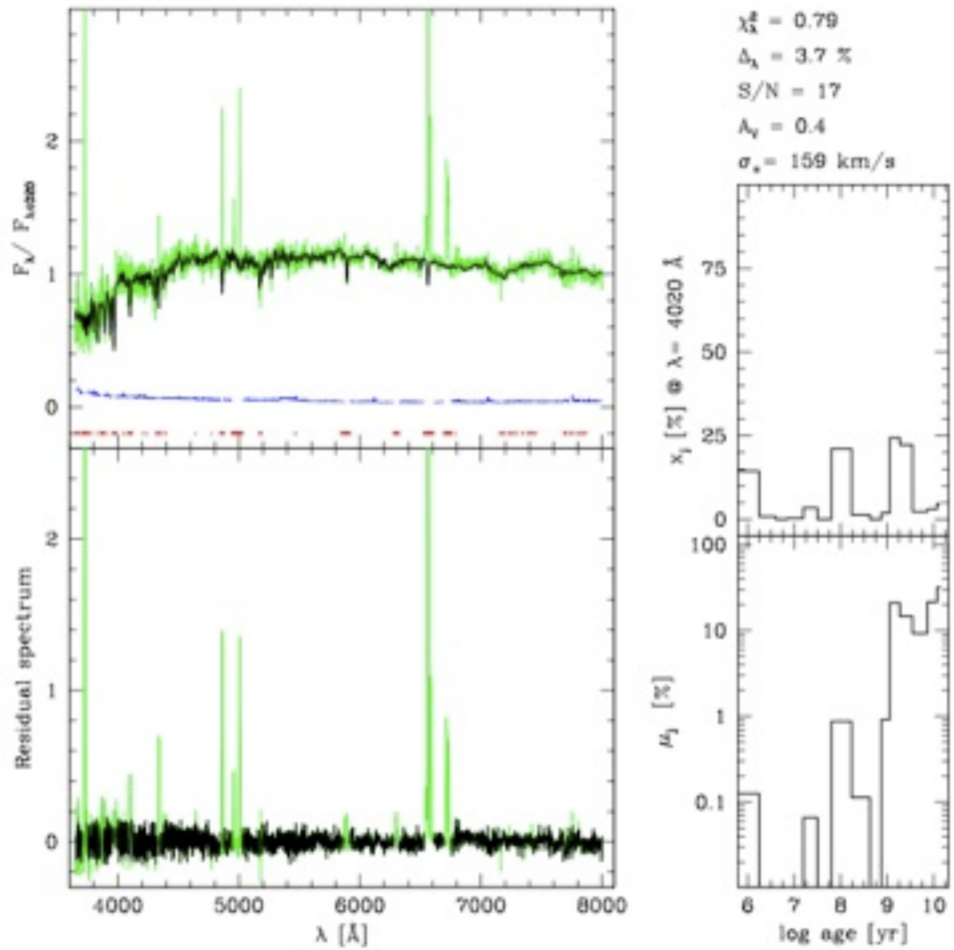


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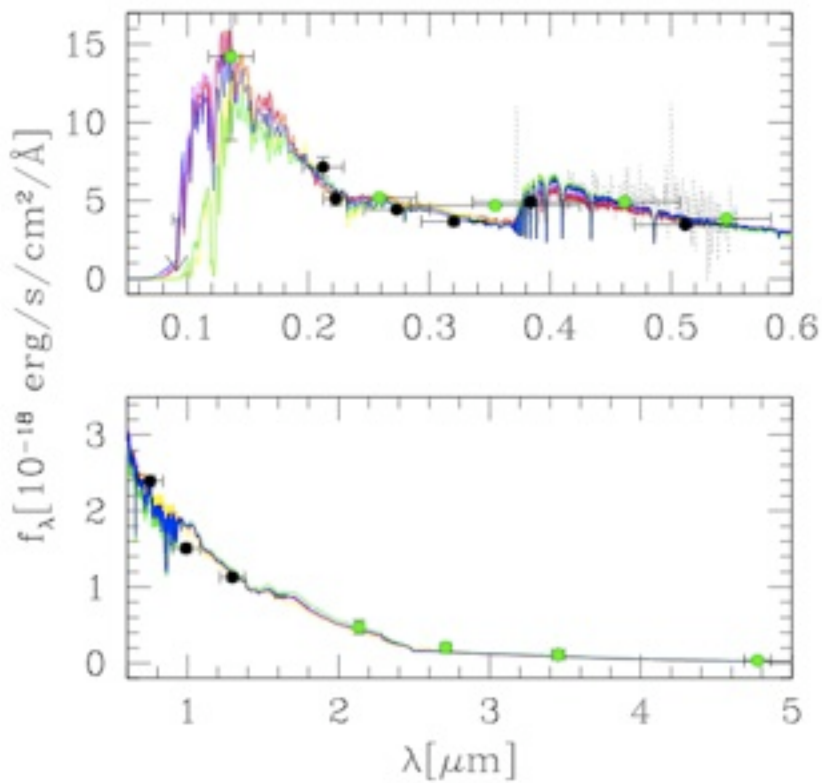
*Mateus et al. 2006*

**Distant galaxies** → **only photometry available**

## From SED

Broad band photometry from UV to near IR




**Single Complexe Stellar Population fitting**
*[Papovitch et al 2001, Shapley et al. 2001, Erb et al. 2006]*
Best-fit library of a simple CSP: exponential decay star formation history (tau, Z, age, Av)

**Two-burst components** *[Papovitch et al. 2001, Cole et al. 2001, Schawinski et al. 2007]*
Linear combination of two simple CSP

**Random burst** *[Kauffman et al. 2003, Brinchmann et al. 2004, Salim et al. 2005]*
Best-fit to library of templates with a wide range of SFH

Due to the small number of constrains and the degeneracy of the problem, SED-fitting methods use methods with priors on SFH

## The case of Starburst galaxies

- ♣ Starburst galaxies can not be approximated by a single stellar population
- ♣ Issue of the low mass stars hidden by the young stars even more dramatic

e.g. single CSP tend to underestimate the mass in starbursts by 25% ***[Fontana et al. 2004, see also Wuyts et al. 2009]***

Our aim was to derive SFH from SED

Enable to recover the old stellar population in a SED dominated by young stars

## First step: assuming a more complex star-formation history

non-parameterized SFH approach, such as full-spectra fitting method

$$F(\lambda) = \sum_{i=0}^{N_\star} x_i T^i(\lambda) \otimes Dust(E(B-V), R_V)$$

Linear combination of 6 CSPs ($\tau$=100Myr) or SSPs:

- ♠ 2 young ($t_{age}$< 100Myr)
- ♠ 2 intermediate ($t_{age}$ <1Gyr)
- ♠ 2 old ($t_{age}$>1Gyr)

$\otimes$

Extinction only on the 2 younger stellar populations:

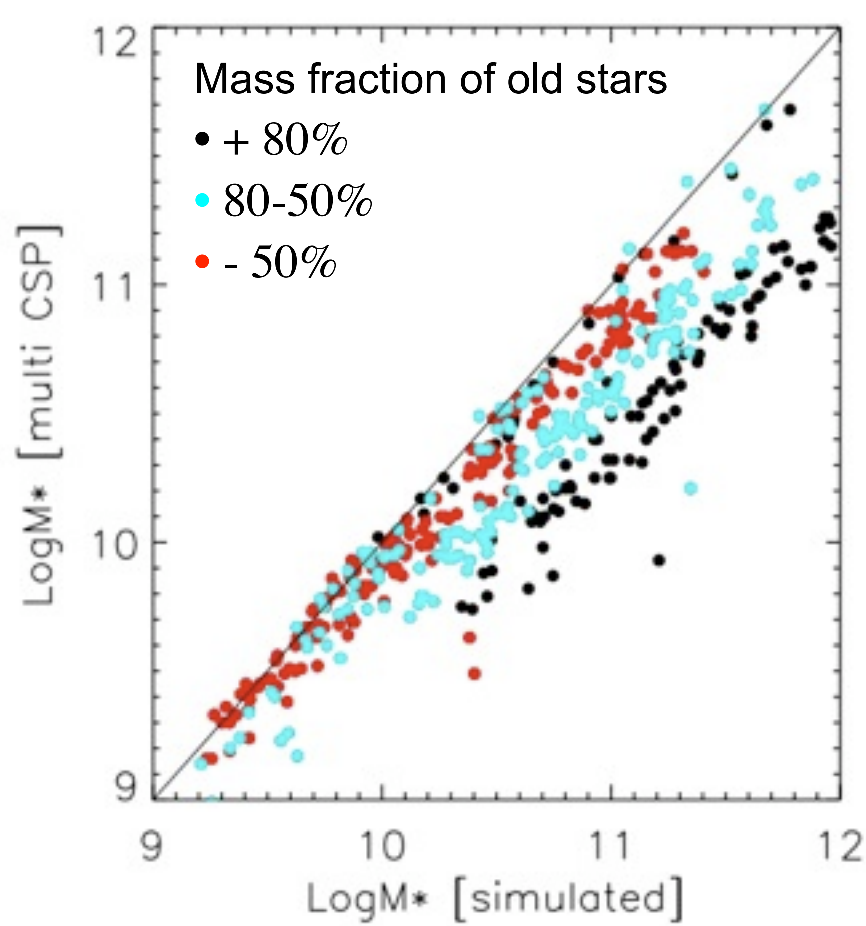
Cardelli law, E(B-V), $R_V$

=

8 free parameters

# First step: assuming a more complex star-formation history

non-para




**Degenerate problem!**

Linear c ger
or SSPs

♠ 2 you

♠ 2 inte

♠ 2 old (

8 free parameters

## Second step: SFR constrain

$$SFR_{Total} = SFR_{UV} + SFR_{IR}$$

Constrains amount of young stars (< 100 Myrs ) and a cascade of other quantities:

♠ the slope in blue band due to extinction

♠ the amount of intermediate age populations in blue and green band

SFR constrain add by penalty function:

$$P(SFR) = \left(\frac{SFR_{obs} - SFR_{model}}{\sigma SFR_{obs}}\right)^2$$

$$\chi^2(x^i, E(B-V), R_V, SFR_{obs}) = \chi^2_{photo}(x^i, E(B-V), R_V) + P(SFR)$$

create a plethora of local minimum in $\chi^2$-space

Need a meta-heurestic method such as genetic code, simulated annealing or **Swarm intelligence algorithm**

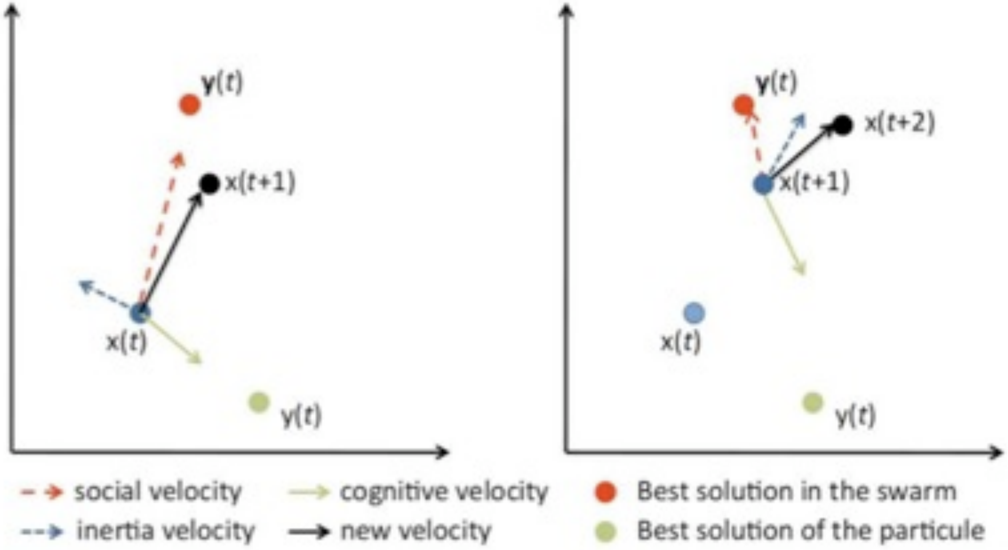
## The Swarm intelligence algorithm

N particles randomly distributed in the parameter space and with initial velocity vector

At each interaction the position is update and the velocity vector recalculated

$$v_{i,j}(t) = w v_{i,j}(t-1) + c_1 r_1 (p_{i,j}(t-1) - x_{i,j}(t-1)) + c_2 r_2 (p_{g,j}(t-1) - x_{i,j}(t-1))$$

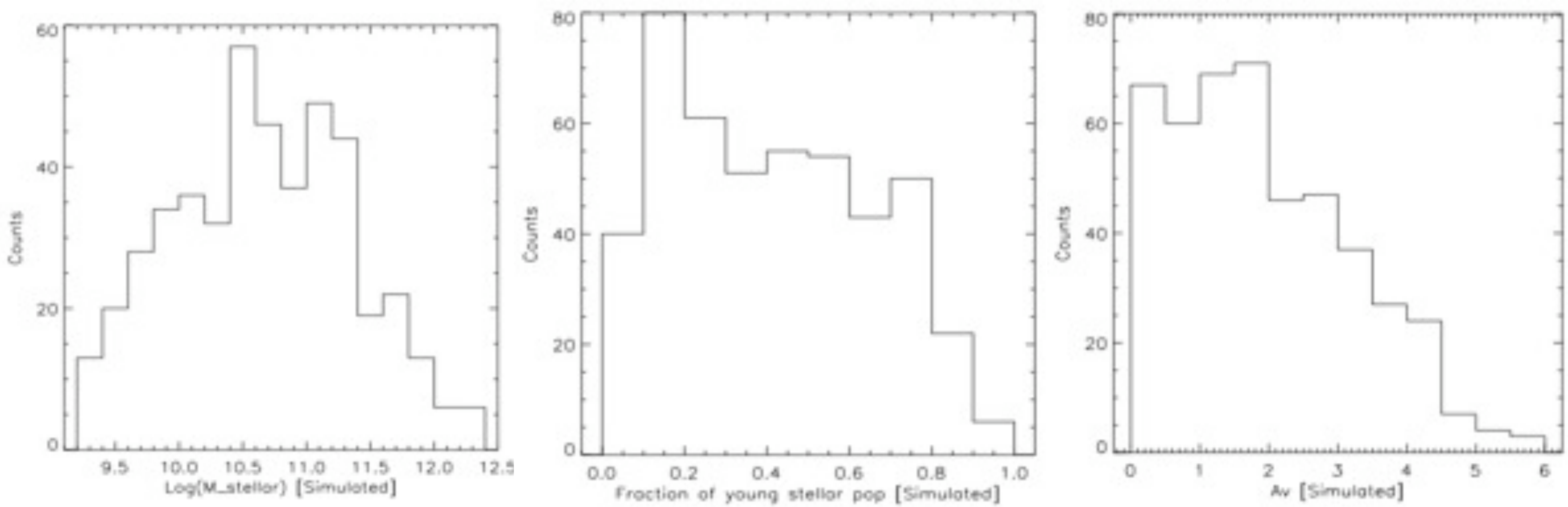
$$x_{i,j}(t) = x_{i,j}(t-1) + v_{i,j}(t)$$




*c1 - Self recognition component*
*c2 - Social component*
*w - Inertia*

## Fake galaxies library

Simulate intermediate mass galaxies at z~0.6




Combination of 6 CSPs with $\tau$=100Myr (Charlot and Bruzual 2007):

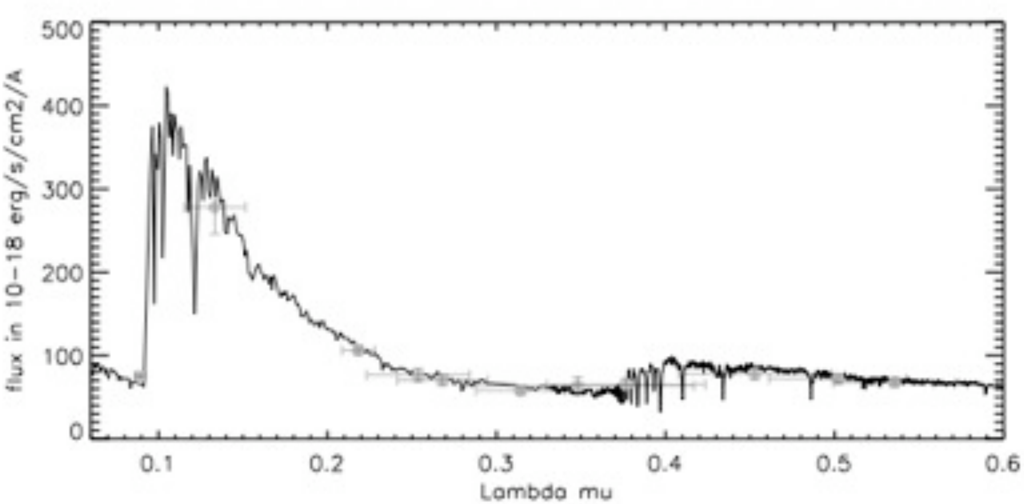
5 Myr, 200 Myr, 500 Myr, 1 Gyr and 4 Gyr

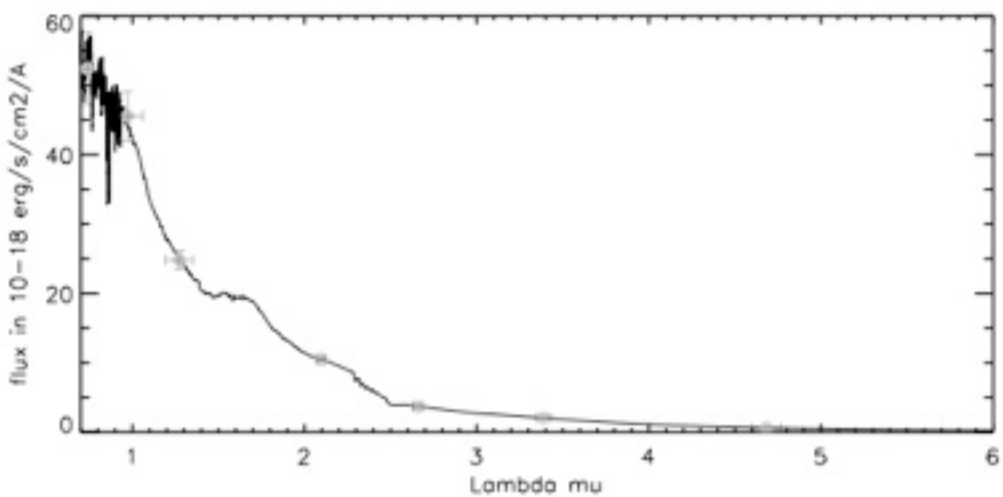
Cardelli extinction law:
E(b-v)=[0,1]
Rv=[2-6]

} Random SF history

Generate SED (17 filters) and optical spectrum

## Testing with fake galaxies

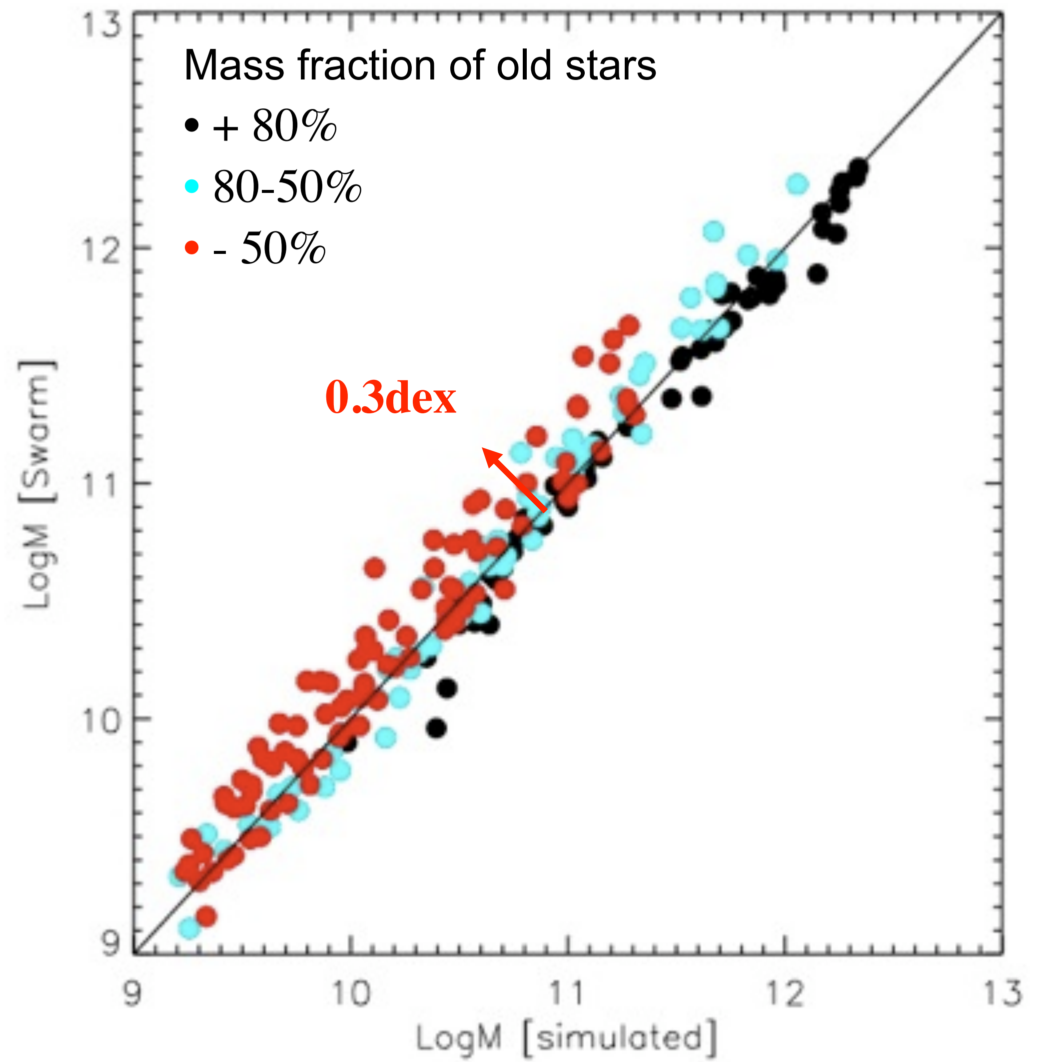



Preliminary results

The software is in optimization and test phase.

# Testing with fake galaxies




Preliminary results

The software is in optimization and test phase.

LogM retrieved within a random error of 0.3 dex and systematic +0.1 dex for very young galaxies

**However**

Test with longer convergence parameters:

<0.1dex random

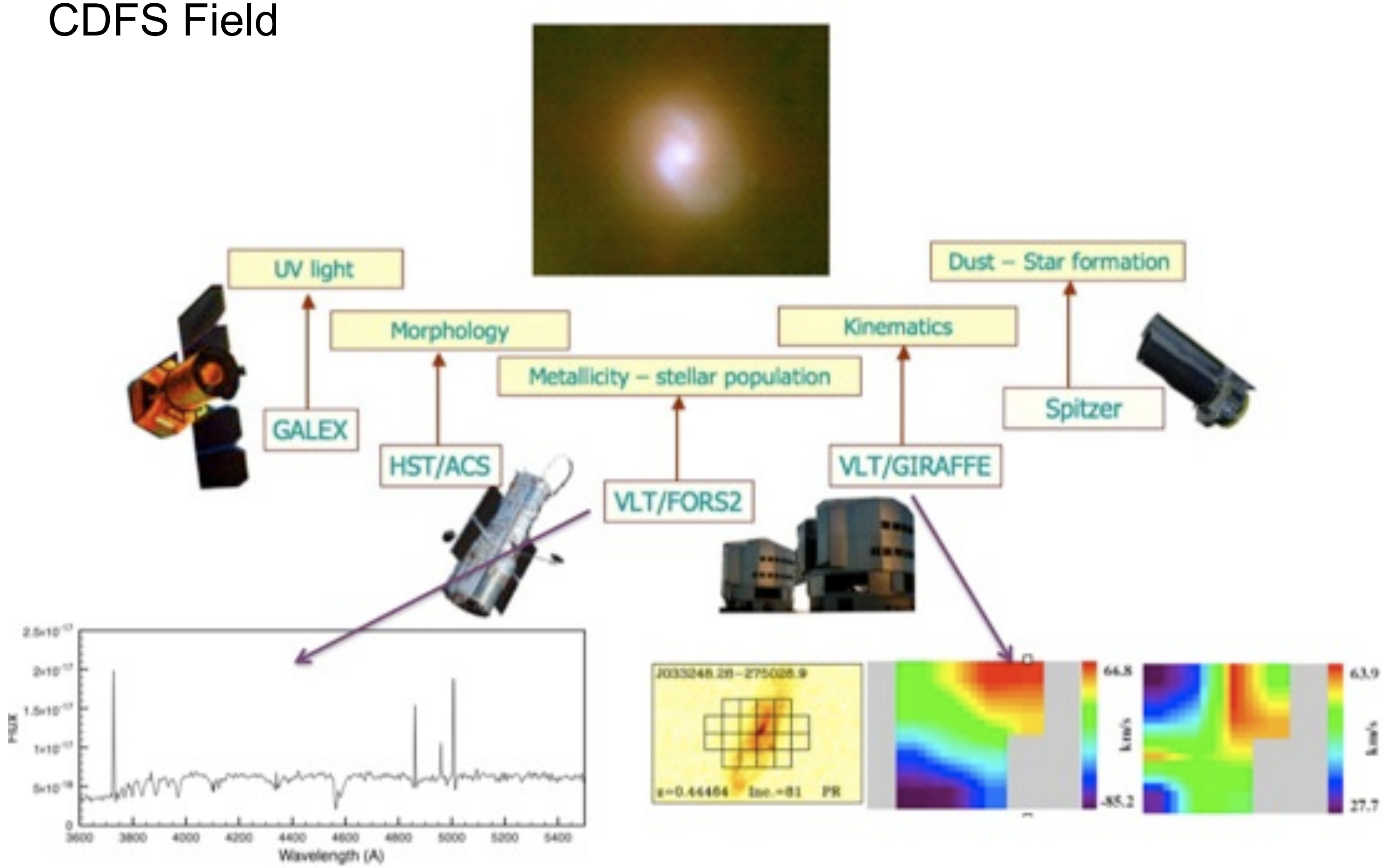
# IMAGES: a multi-instrumental study of distant galaxies

Intermediate MAss Galaxy Evolution Sequence *See F. Hammer talk*

**Sample selection**
$M_J < -20.3$ & $0.4 < z < 0.9$
CDFS Field

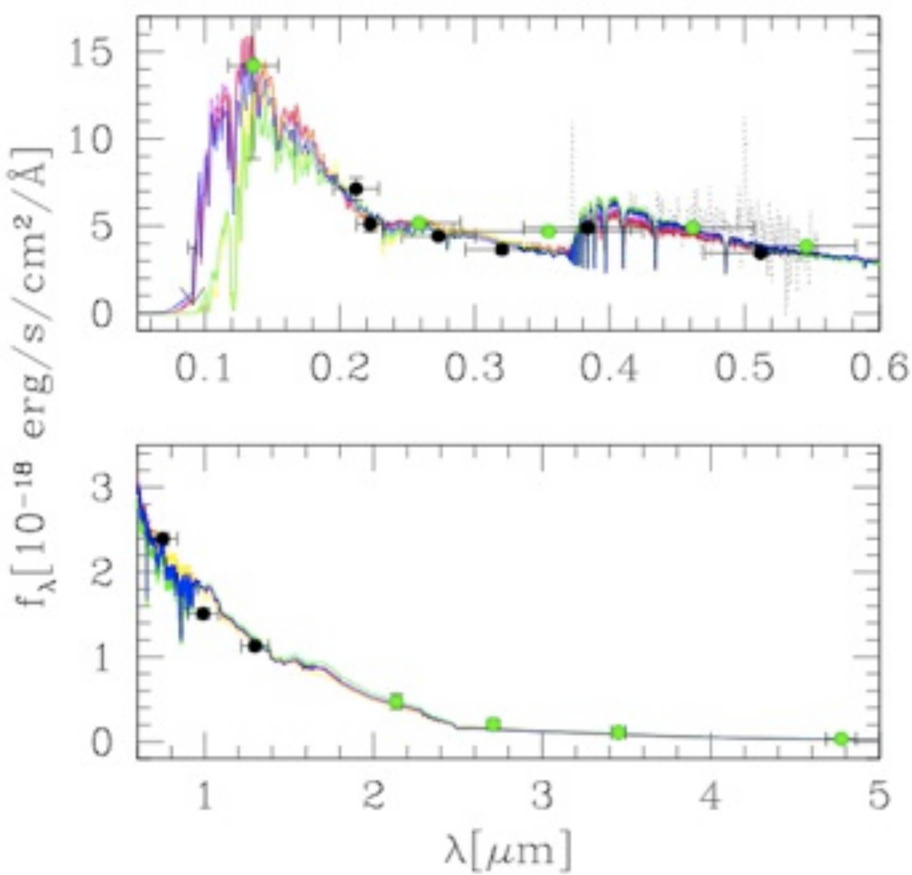
⇒

Intermediate-mass galaxies
$M_{stellar} > 1.5\ 10^{10} M$



# IMAGES: broad band photometry

From GOODS




**Ultraviolet**

Galex nuv and fuv

**Optical**

- ACS/HST B,V,R,I,Z
- EIS U,B,V,R,I

**Near-IR**

ISAAC J,H,K

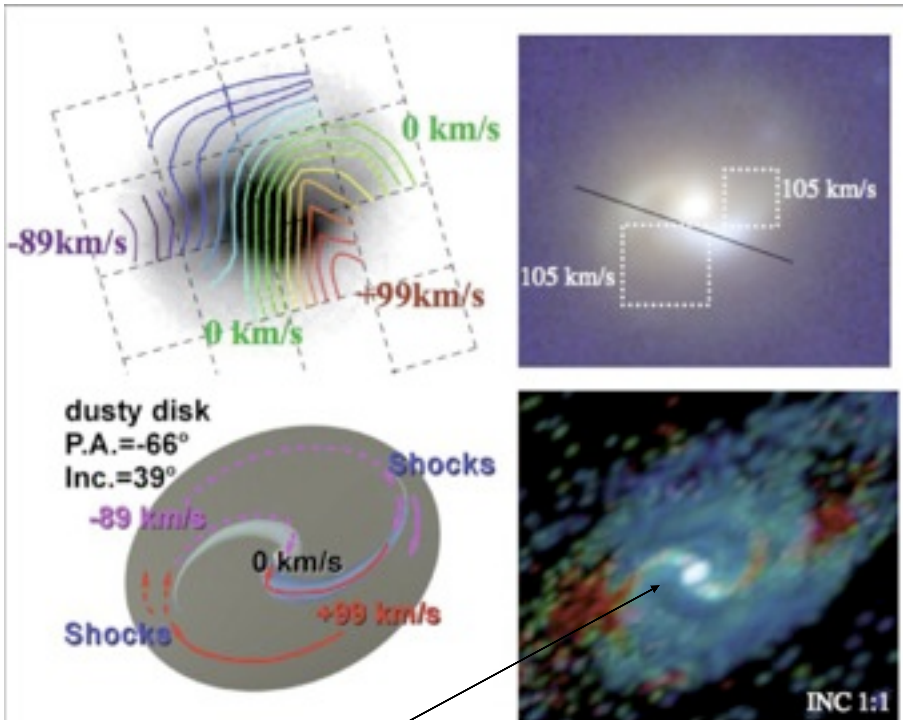
**mid-IR**

IRAC 3.6μm, 4.8μm, 5.8μm, 8μm

**=** 17 bands + 24 μm Spitzer

# A forming dust-enshrouded disk at z=0.43

## J033241.11-275215.5 *Hammer et al. 2009*

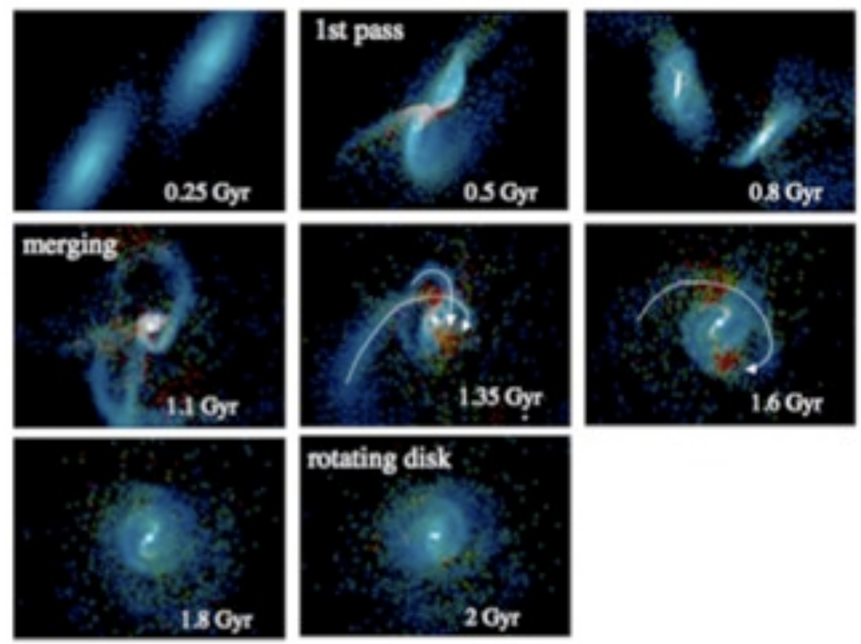



Combining morphology + kinematics

=> Gas rich 1:1 major merger remnant

*Barnes, 2002*

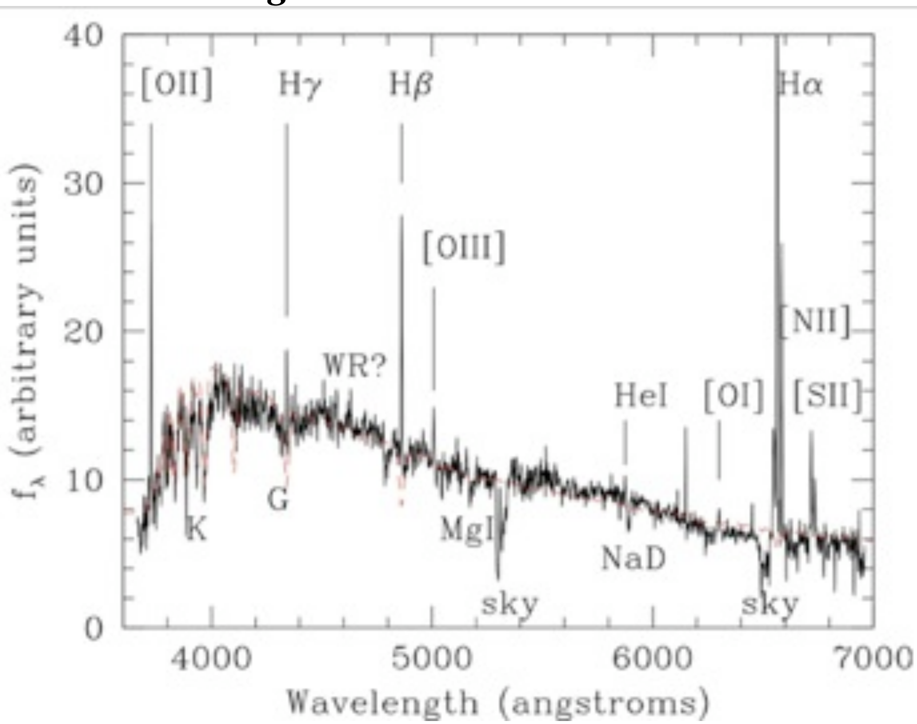
Gas, INCLINED, 1:1




**Central structure** redistributing the angular momentum of the infalling material towards the bar and buldge

## Integrated spectroscopy from FORS2/VLT

R~1000 ***Rodrigues et al. 2008***




### Properties of the ISM

**Over-solar metallicities:**

Log(O/H)+12 (R23)=9.08

**Very young and hot stars**

- Possible WR bump

- He 5875A line
(usually in pristine gas)

**No evidence for outflow**

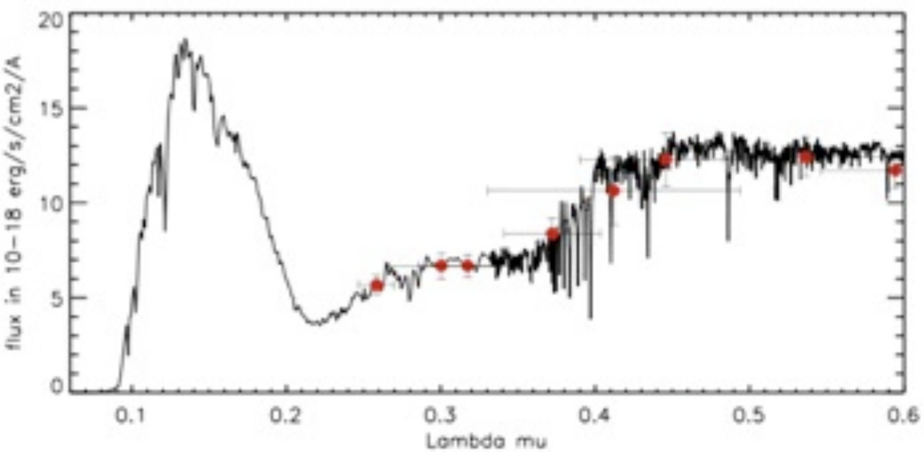
- Δv (emi-abs)=15 km/s

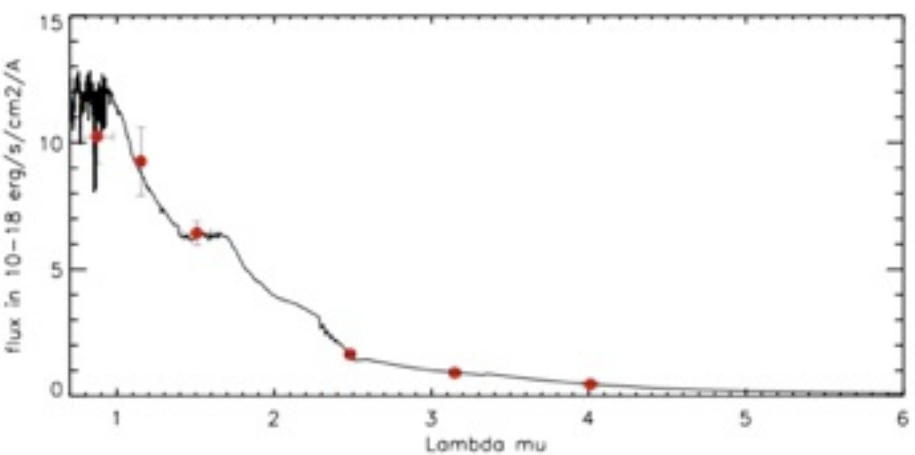
### Stellar population

Full spectra-fitting (Starlight)

| *Young* $t_{age}$ *<300Myr* | *Intermediate* *300<*$t_{age}$*<1Gyr* | *Old* $T_{age}$*>1Gyr* |
|---|---|---|
| 20% | 33% | 47% |

## SED fitting with the SFR constraint




| *Young* $t_{age}$ *<300Myr* | *Intermediate* *300<*$t_{age}$*<1Gyr* | *Old* $T_{age}$*>1Gyr* |
|---|---|---|
| 15% | 15% | 70% |

Stellar populations are in agreement with the SFH predicted by the model

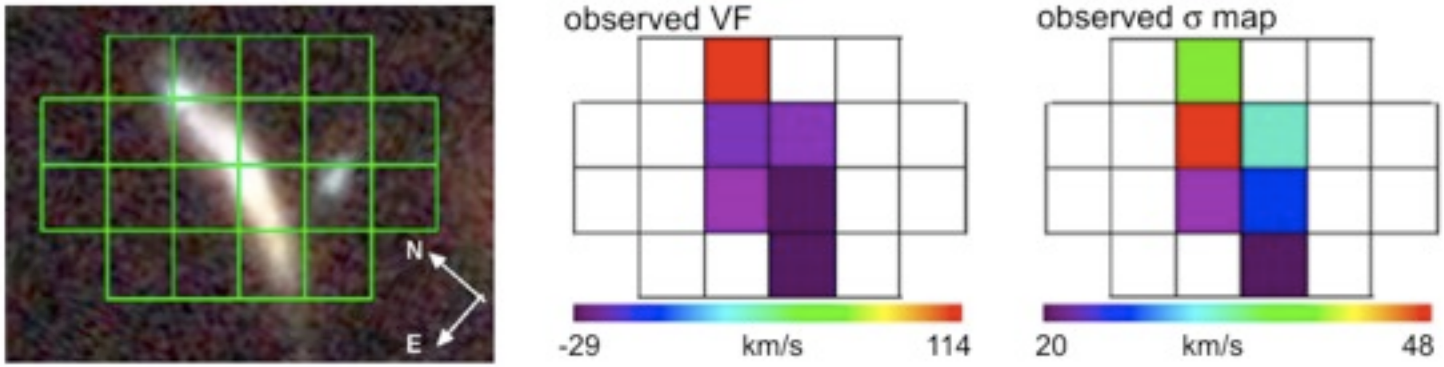
### Lower limits of gas fraction

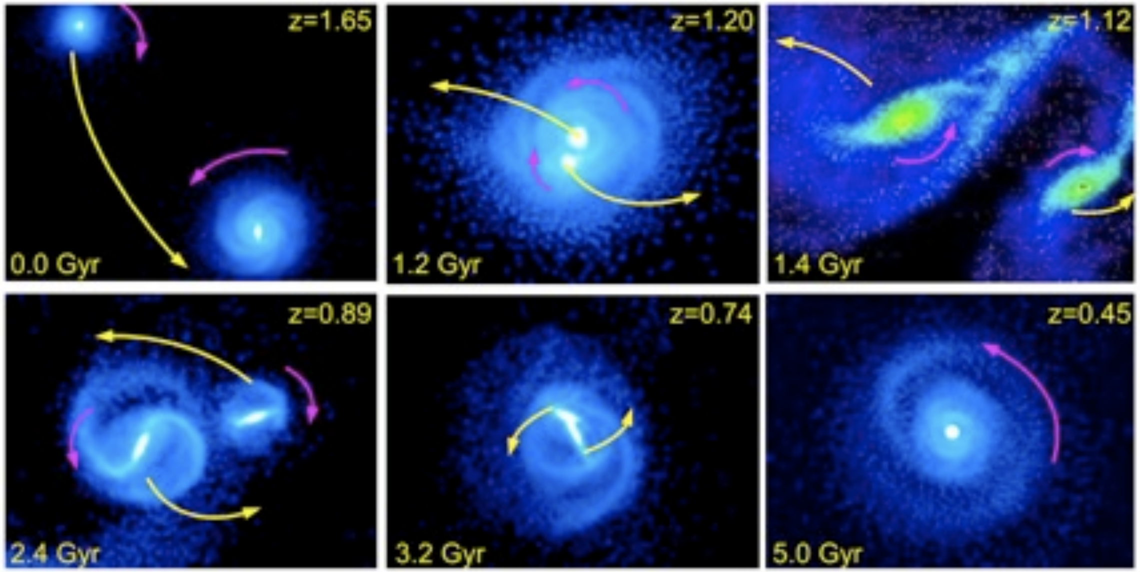
$F_{gas}$ = 37% [from inverted KS law]
$F_{star}$ (formed during merger)= 30%±10% (less than 1Gyrs)
$F_{gas}$ (in the progenitor) = 48% ±10%

Gas fraction in progenitor is concordant with the rebuilding of disk after major merger ***(Barnes 2002,Roberston 2006, Hopkins 2009)***

## A face-on galaxy at z=0.7

J033227.07-274404.7 *Fuentes-Carrera et al. A&A 2010*

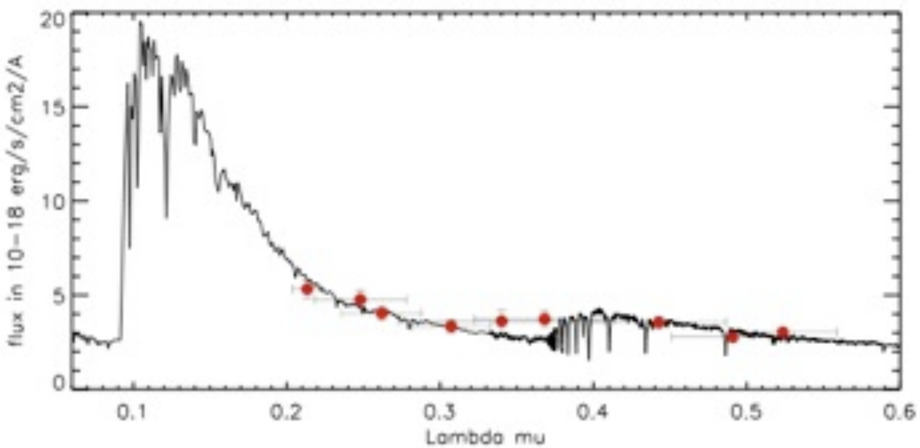


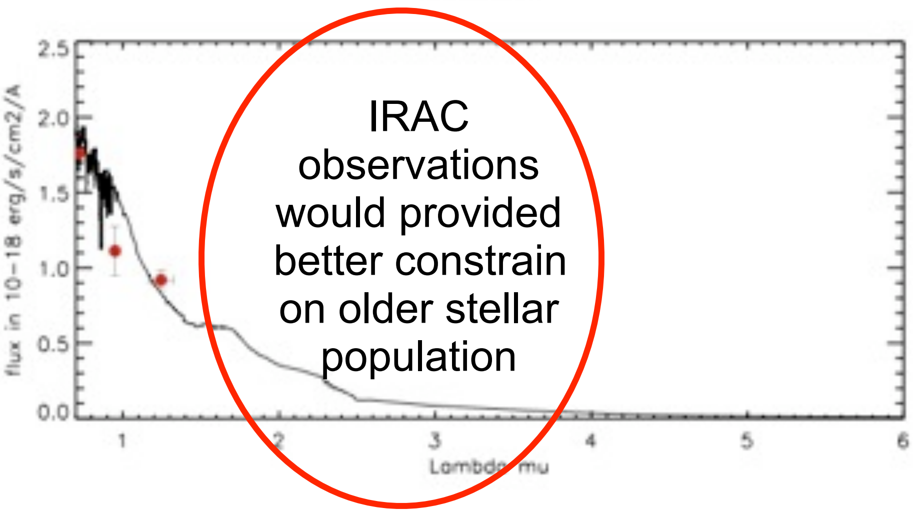




Major merger

ZENO code
Barnes 2002

## SED fitting with the SFR constrain




| *Young* | *Intermediate* | *Old* |
|---|---|---|
| *$t_{age}$ <200Myr* | *300<$t_{age}$<1Gyr* | *$T_{age}$>1Gyr* |
| 13%±0.1 | 32%±0.2 | 55% |

*In a confidence level interval of 68%*

Fractions of stellar population are in agreement with the SFH predicted by the model

### Lower limits of gas fraction

$F_{gas}$ = 44% [from inverted KS law]

$F_{star}$ (formed during merger)= 33%

$F_{gas}$ (in the progenitor) = 61% ±20%

# Conclusions

♣ Stellar mass is a fundamental but poorly constrain quantity in distant starbursts

♣ Decompose the SED into the stellar populations without no prior on the SFH

♣ Implemented a new method to retrieve stellar population and stellar mass:

Combination of 6 stellar populations + extinction in younger populations

Constrains: Broad-band photometry (n>10) + $SFR_{total}$

♣ Preliminary results on fake galaxies are promising:

Stellar mass can be estimated with an accuracy ±0.1 dex, but not account for model uncertainties

♣ Applied to real data (IMAGES)