The star formation history of Virgo spiral galaxies

Combined spectral and photometric inversion

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Cluster galaxies

Abell 1689

Physical effects acting on galaxy cluster

A. Gravitational:
tidal interaction on time-scale of 100 Myr, and the combined effect of multiple high speed galaxy-galaxy encounters and the potential of the cluster as a whole, the so-called harassment

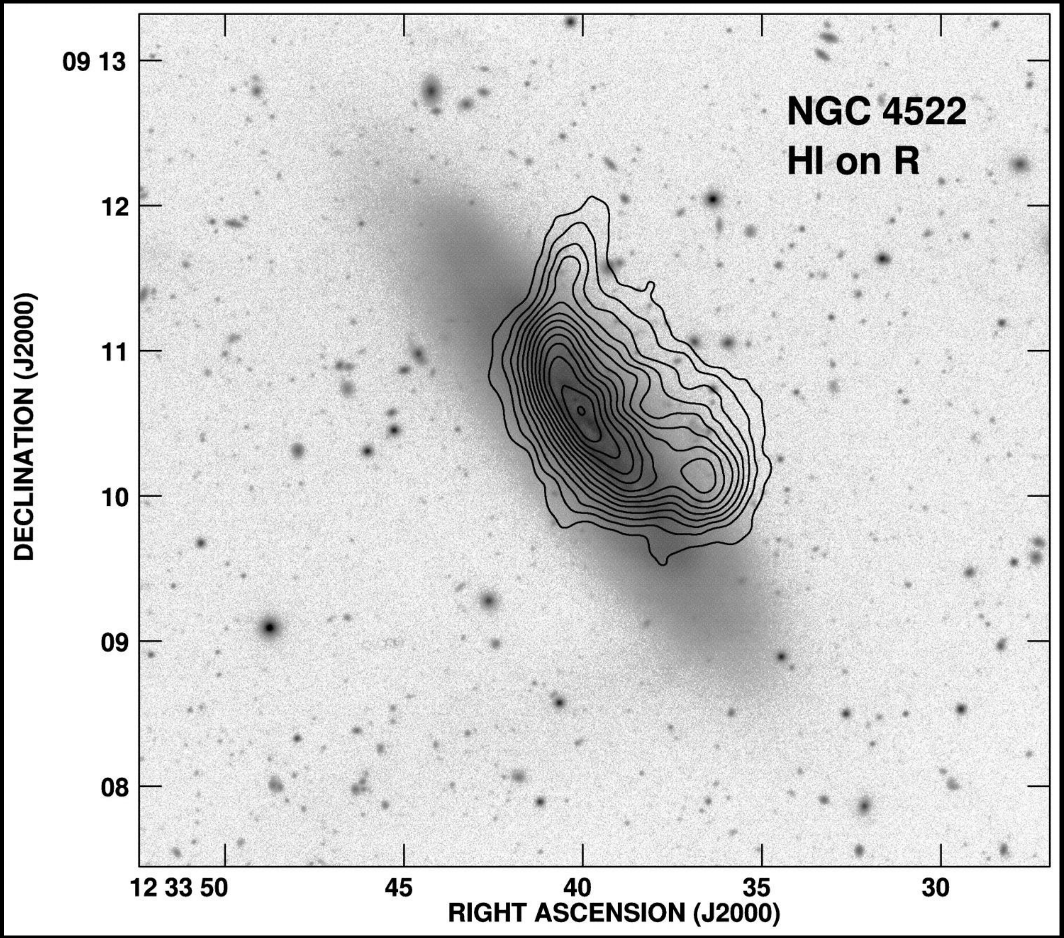
B. Hydrodynamical:
ram pressure stripping, (time scale, few tens Myr)
viscous stripping (time scale, 1 Gyr) and thermal evaporation

C. Hybrid: pre-processing

Ram pressure stripping

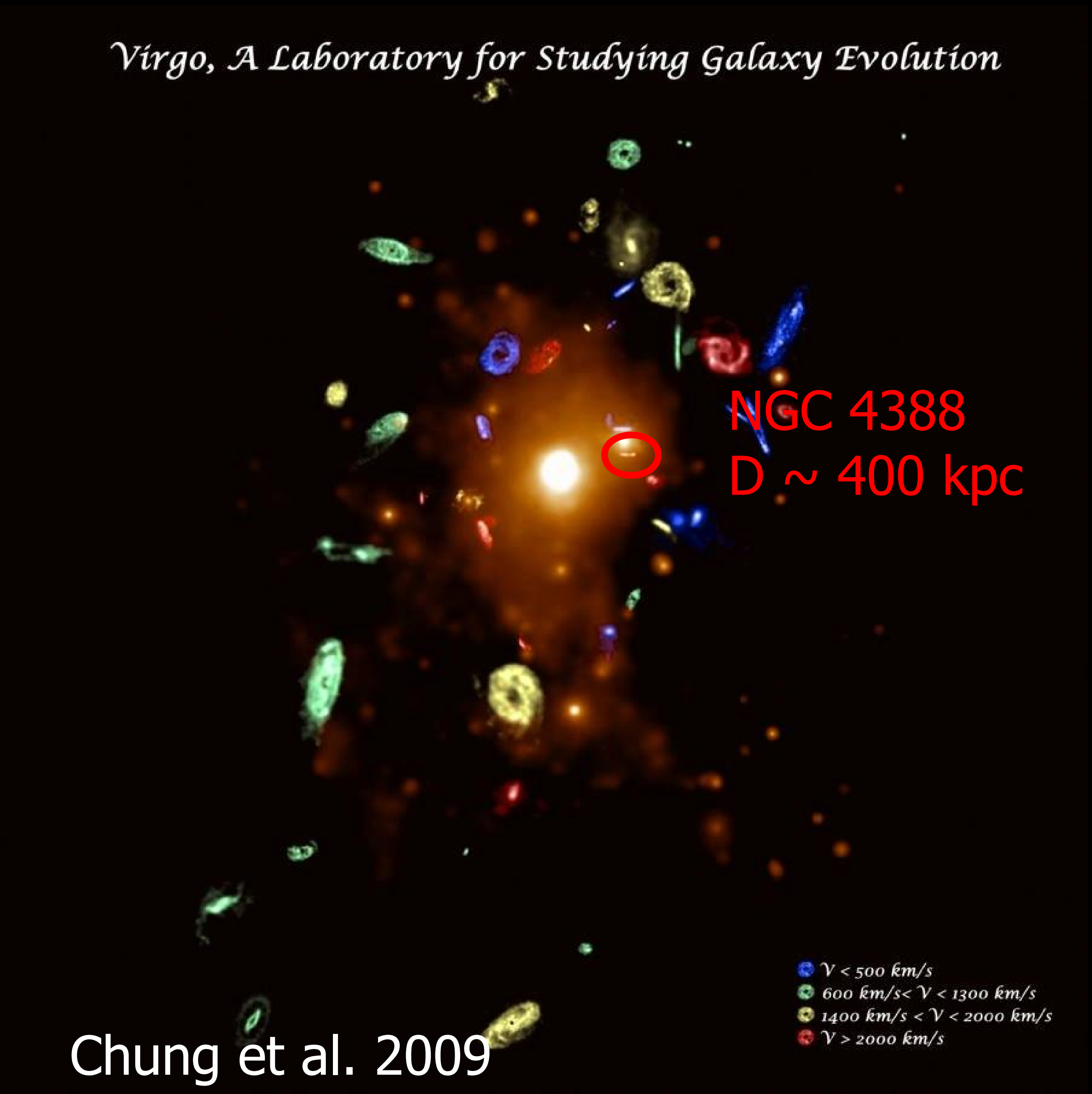
Physical effects:

- Hydrodynamical: ram-pressure stripping, viscous stripping and thermal evaporation



Kenney et al. 2004

Virgo Cluster



D ~ 17 Mpc

Mass = 10^15 Msol

Radius = 2.2 Mpc

N gal = 1300 - 2000

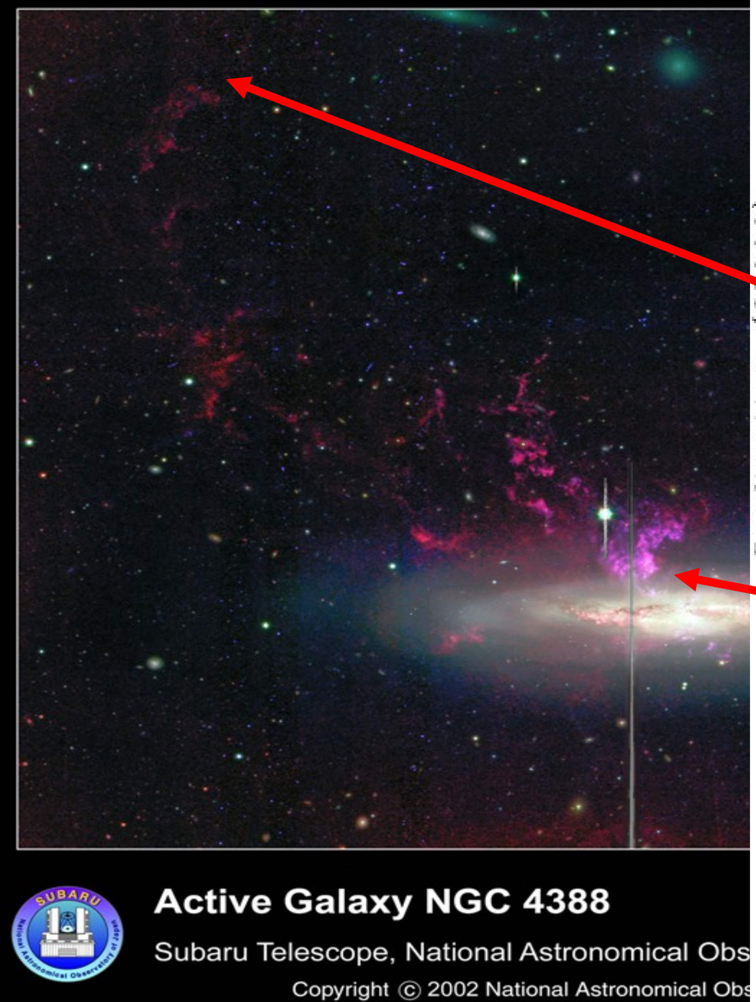
Spiral rich

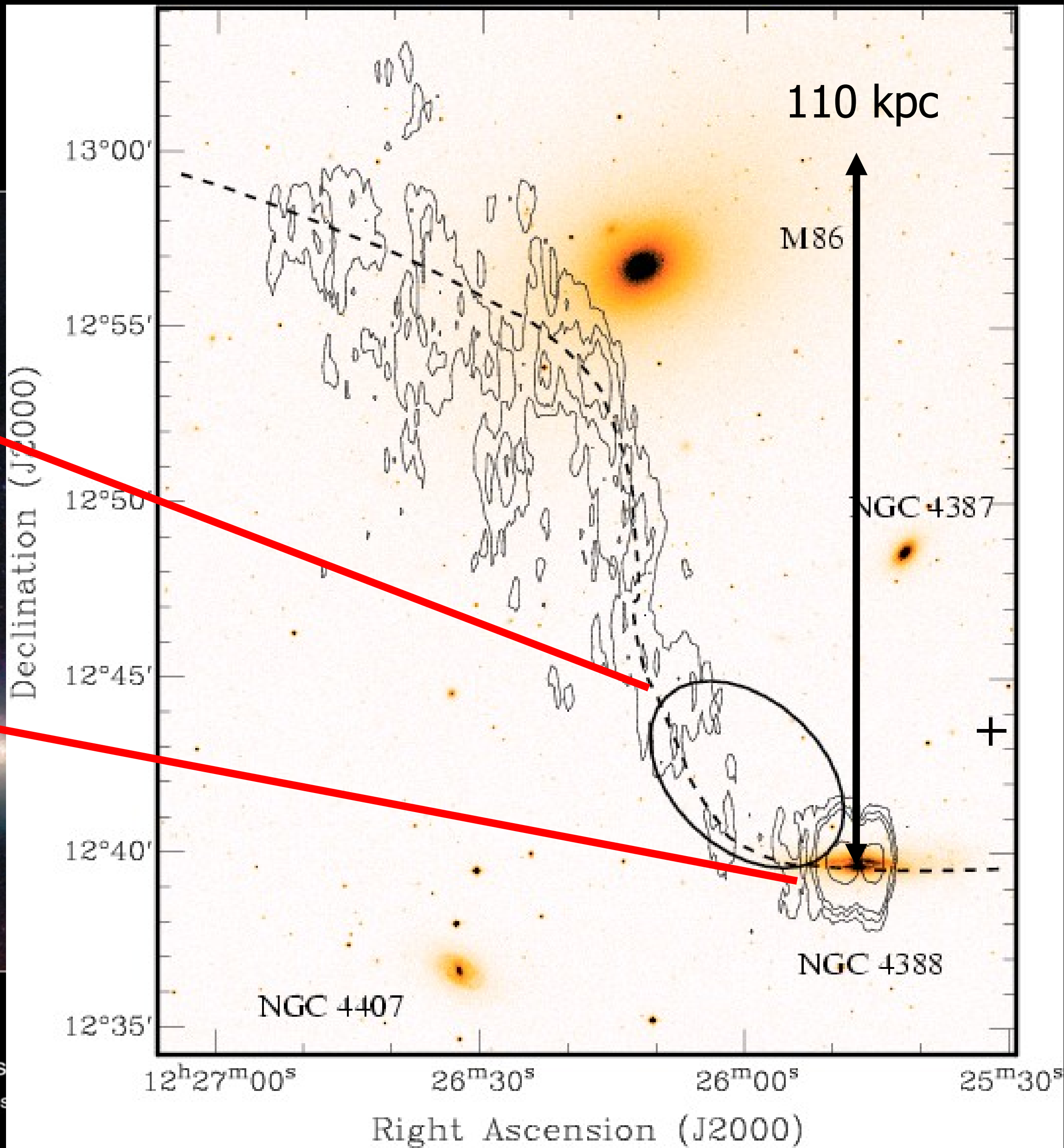
Dynamically young

NGC 4388

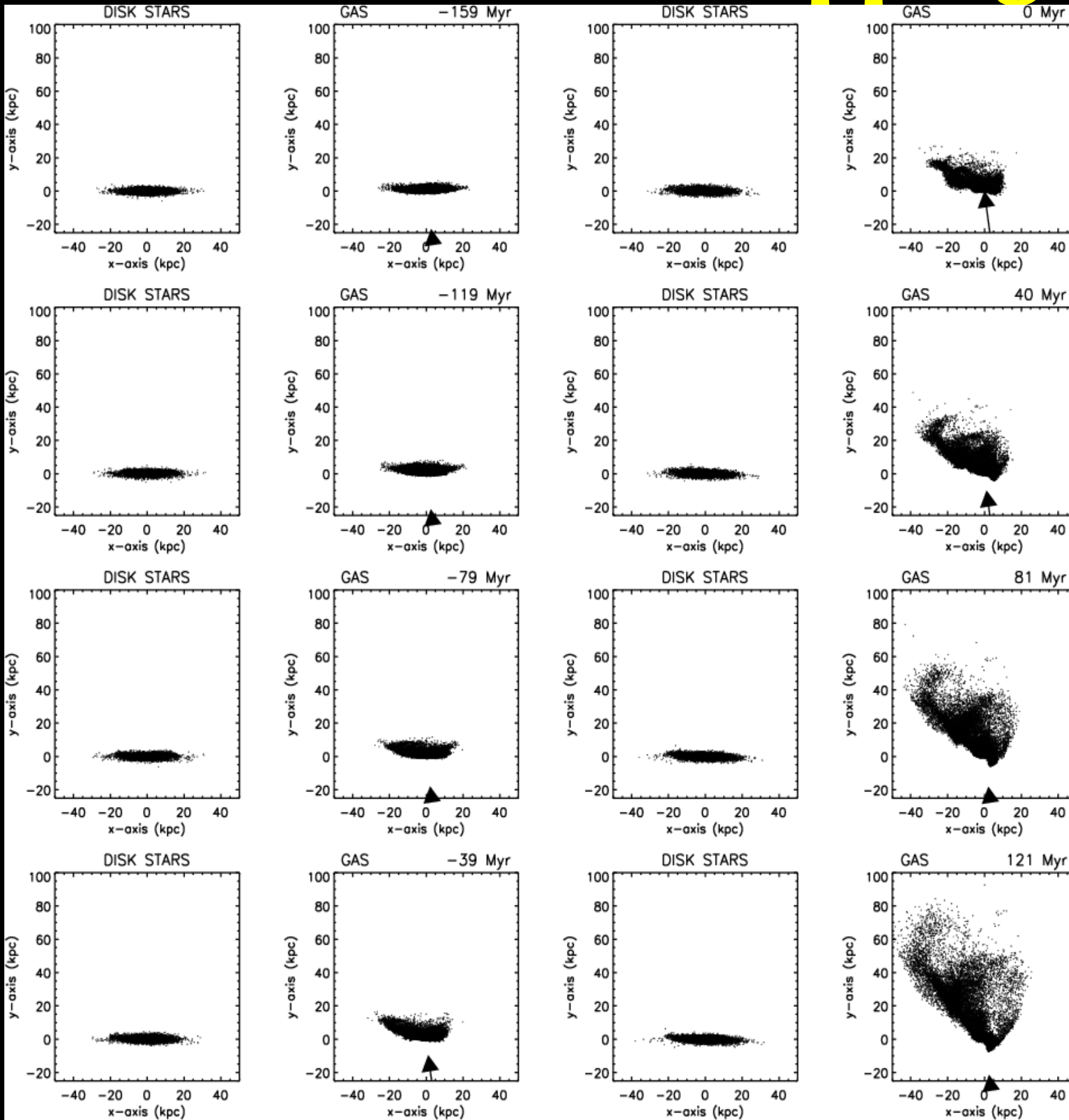
Oosterloo & van Gorkom 2005

Yoshida et al 2002





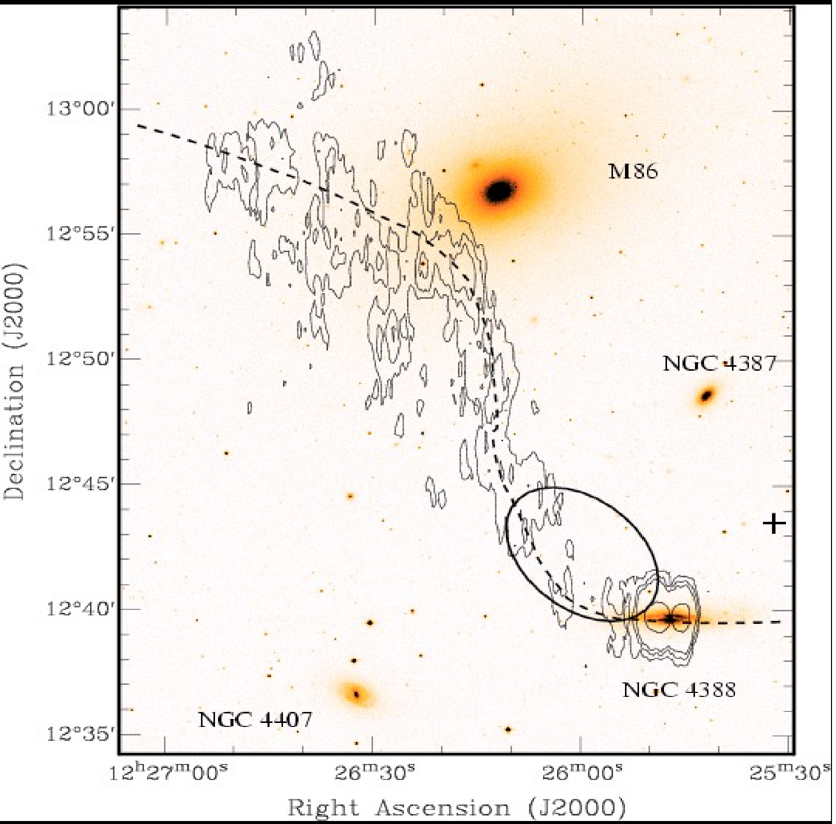
Ram Pressure Stripping Scenario

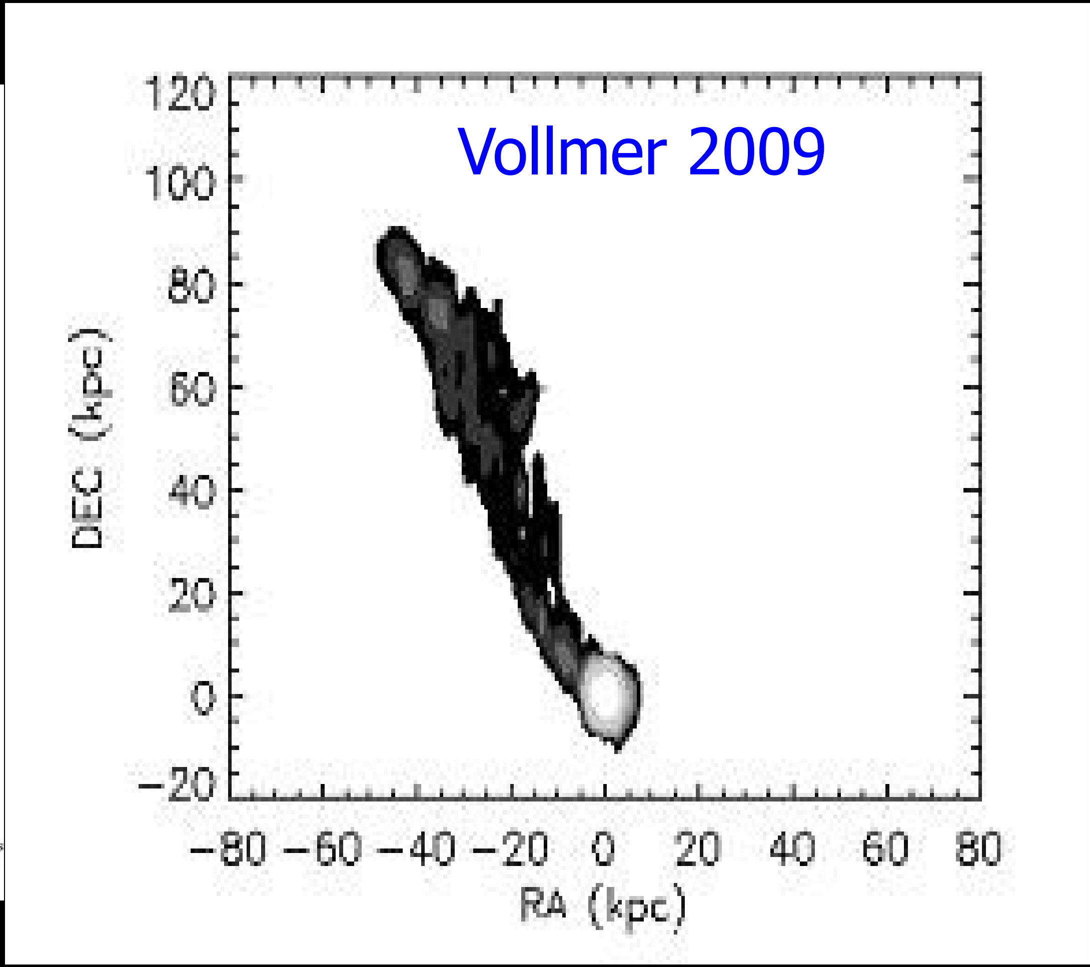


Vollmer et Huchtmeier, 2003

Ram Pressure Stripping Scenario 2

Oosterloo & van Gorkom 2005





time since peak ram pressure ~ 170 Myr

stripping age: time elapsed since SF has dropped by a factor 2 from its pre-stripping value

Aims

1. New approach combining spectral and photometric data: parametric and non parametric analysis

2. Results obtained using mock data

3. Application to the real data: NGC 4388 case

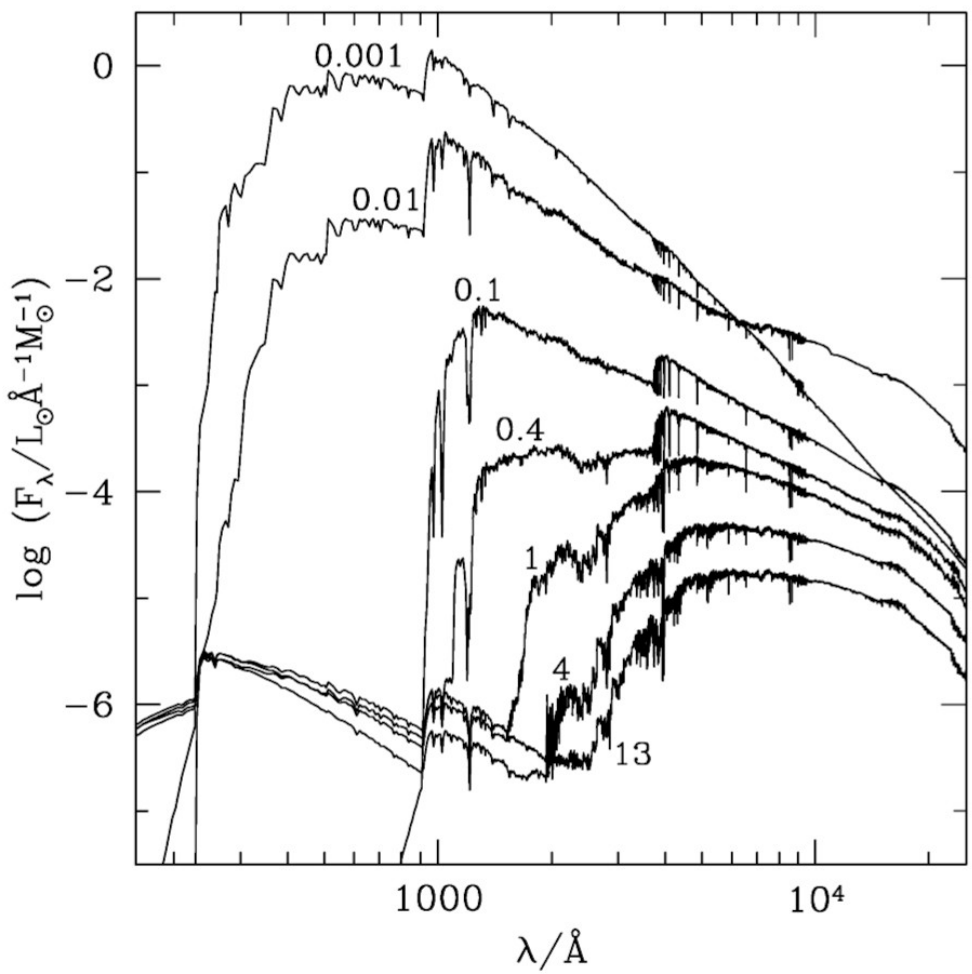
4. Non parametric and parametric results

5. Conclusions and outlook

METHOD

fitting SEDs (Spectrum)

$$F_{\rm rest} = \int_{t_{\rm min}}^{t_{\rm max}} {\rm SFR}(t) B^0(\lambda, t, Z(t))\ {\rm d}t \longrightarrow \int_{t_{\rm min}}^{t_{\rm max}} \Lambda(t) B(\lambda, t, Z(t))\ {\rm d}t$$



Bruzual & Charlot 2003

fitting SEDs (Spectrum)

$$F_{\rm rest} = \int_{t_{\rm min}}^{t_{\rm max}} {\rm SFR}(t) B^0(\lambda, t, Z(t))\ {\rm d}t \longrightarrow \int_{t_{\rm min}}^{t_{\rm max}} \Lambda(t) B(\lambda, t, Z(t))\ {\rm d}t$$

NPEC

$$F_{\rm rest} = f_{\rm ext}(\mathbf{E}) \int_{t_{\rm min}}^{t_{\rm max}} \Lambda(t) B(\lambda, t, Z(t))\ {\rm d}t$$

LOSVD

$$\phi(\lambda) = \int_{v_{\rm min}}^{v_{\rm max}} F_{\rm rest}\left(\frac{\lambda}{1+v/c}\right) g(v) \frac{{\rm d}v}{1+v/c}$$

PSF

$$\phi'(\lambda) = \int_{\lambda_{\rm min}}^{\lambda_{\rm max}} \phi(\lambda) {\rm PSF}(\lambda_0 - \lambda)\ {\rm d}\lambda$$

fitting SEDs (Photometry)

New approach: combined analysis of spectral and photometric constraints

$$F_{\rm phot}(b) = f_{\rm ext}(E, \lambda_{\rm eff}) \int_{t_{\rm min}}^{t_{\rm max}} \Lambda(t) B_{\rm phot}(\lambda, t, Z(t))\ {\rm d}t$$

$$\lambda_{\rm eff} = \frac{\int_{\lambda_{\rm min}}^{\lambda_{\rm max}} \lambda\ T_b(\lambda)\ {\rm d}\lambda}{\int_{\lambda_{\rm min}}^{\lambda_{\rm max}} T_b(\lambda)\ {\rm d}\lambda}$$

toward the solution

$$\mathbf{X} = [\mathbf{x}, \mathbf{Z}, \mathbf{E}, E(B-V), \mathbf{g}]$$

SFR MET NPEC Col. Excess SBF

non parametric method

$$Q(\mathbf{X}) = (1-\alpha)\cdot\chi^2_{\rm spec}(\mathbf{X}) + \alpha\cdot\chi^2_{\rm phot}(\mathbf{X}) + \mu\cdot P(\mathbf{X})$$

penalty functions

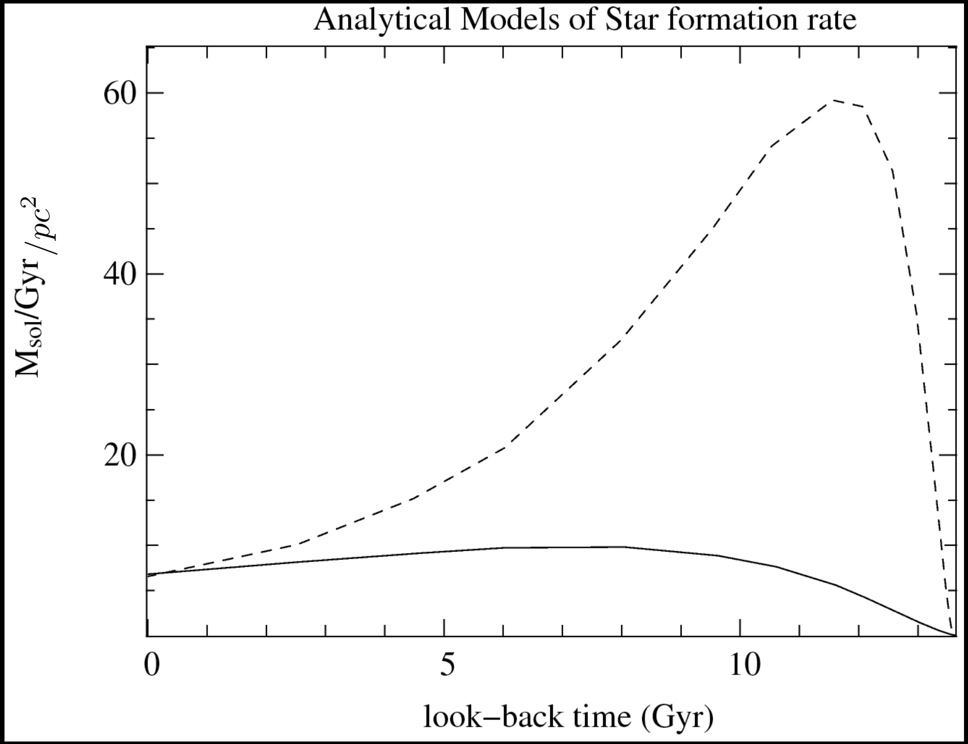
$$\mu\cdot P(\mathbf{X}) = \mu_x P(\mathbf{x}) + \mu_Z P(\mathbf{Z}) + \mu_C C(\mathbf{Z}) + \mu_g P(\mathbf{g})$$

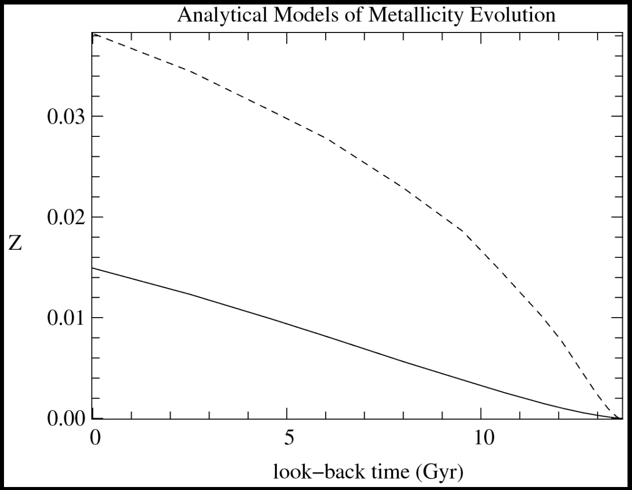
parametric method

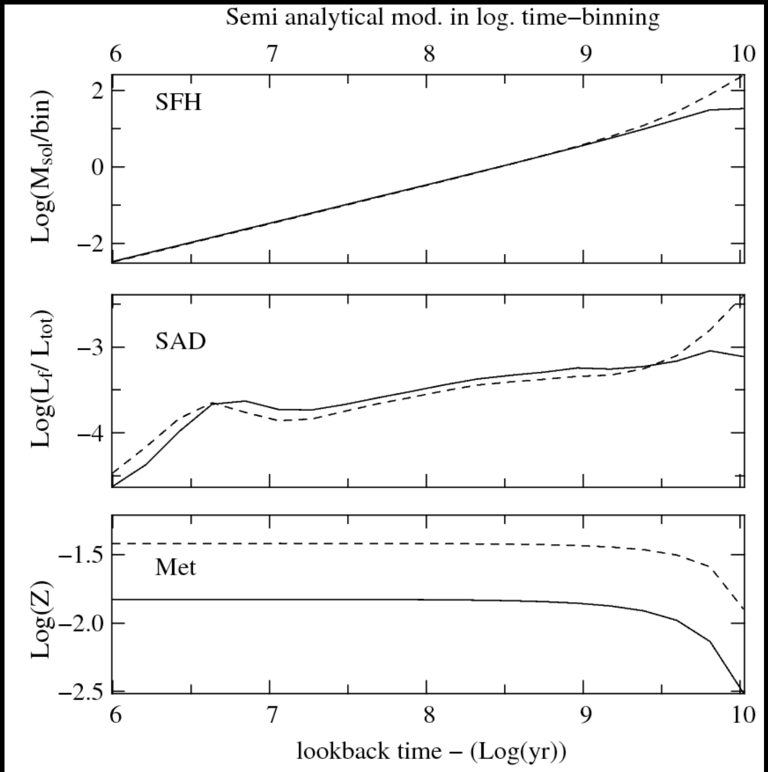
$$\chi^2_{\rm tot}(\mathbf{X}) = (1-\alpha)\cdot\chi^2_{\rm spec}(\mathbf{X}) + \alpha\cdot\chi^2_{\rm phot}(\mathbf{X})$$

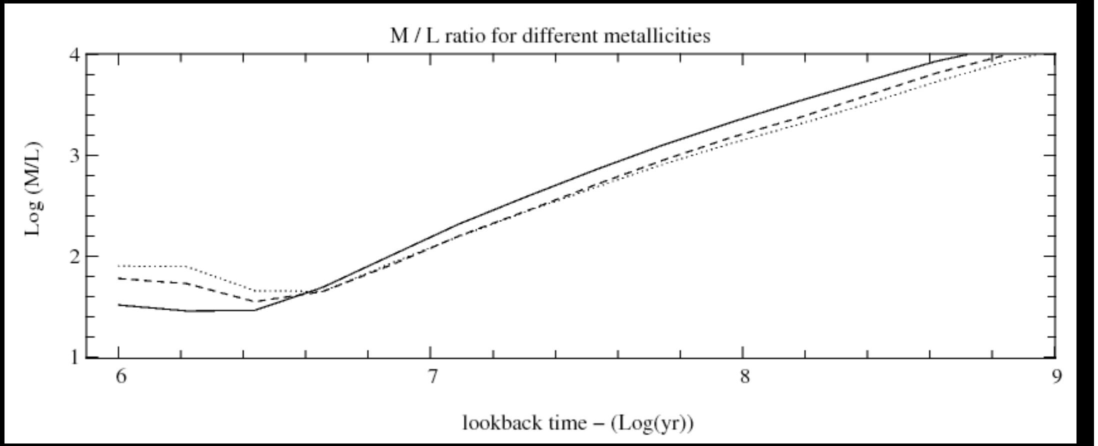
NON PARAMETRIC METHOD:
mock campaign

Semi-analytical models Boissier & Prantzos, 2000



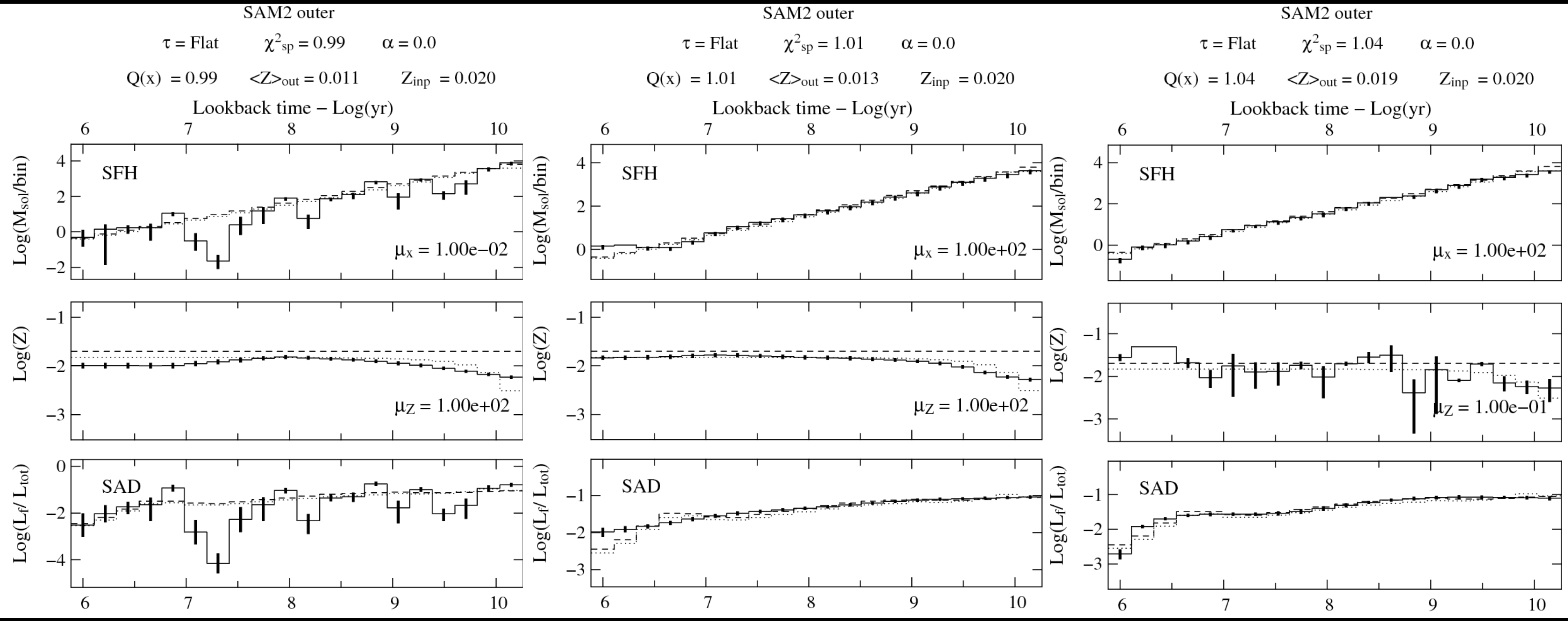






Weight of penalization

$$\mu \cdot P(\mathbf{X}) = \mu_x P(\mathbf{x}) + \mu_Z P(\mathbf{Z}) + \mu_C C(\mathbf{Z}) + \mu_g P(\mathbf{g})$$



Further tests

A. Different initial guesses

B. Photometric and combined analysis

C. Different Star formation Histories

D. Different metallicity evolution (less constrained)

Conclusions: the mock campaign

A. The non parametric method is able to reproduce flat and peaked star formation history and basic trends of metallicity evolution

B. Through Monte Carlo simulations we verified that the results are stable, once the minimization has converged

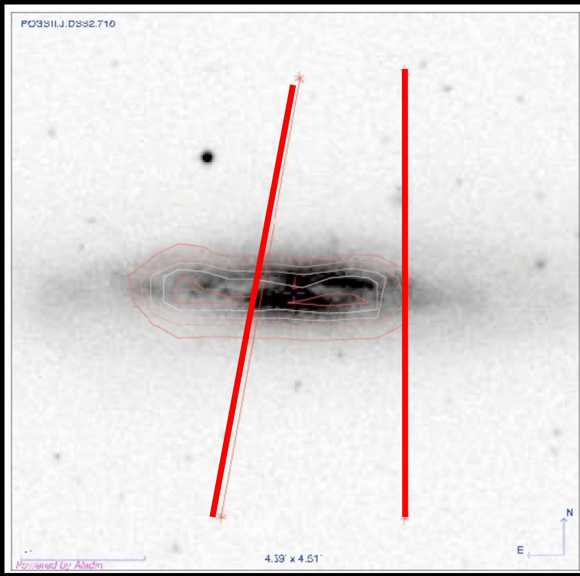
C. The choice of initial condition has no effect on the recovered solution as long as it is reasonable

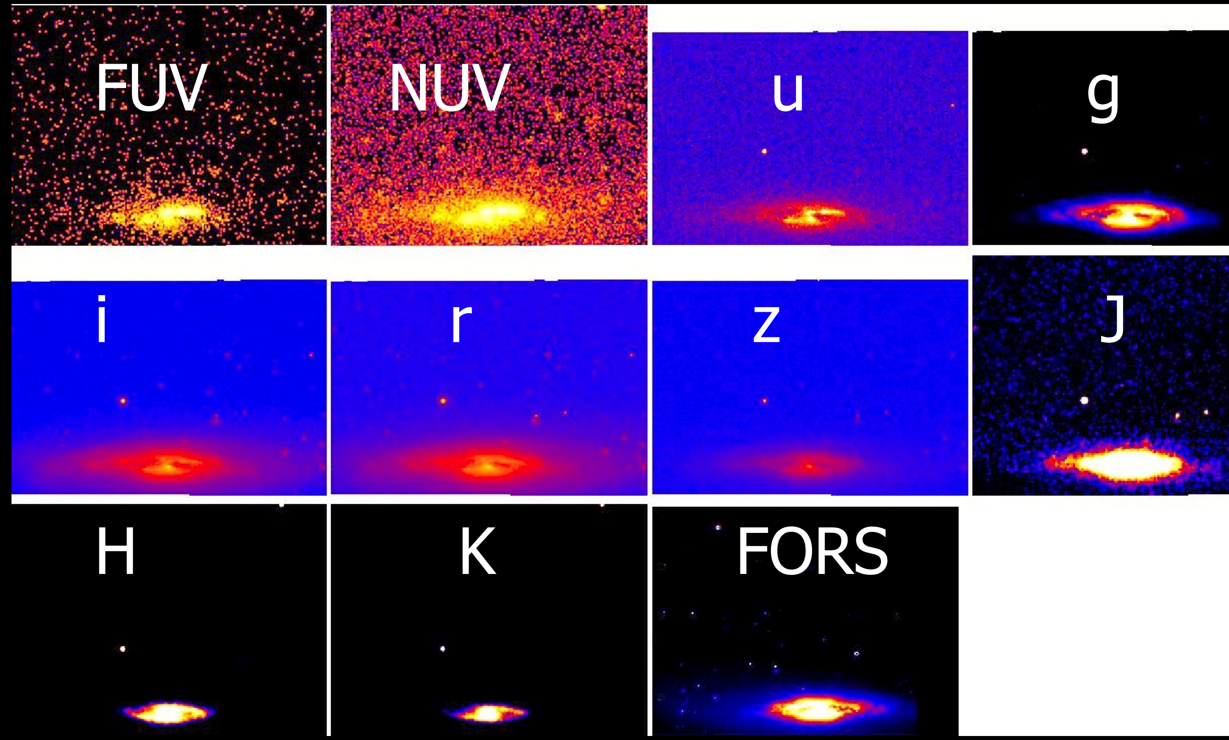
D. There is an inferior limit to the S/N ratio that gives reliable solutions (S/N ~ 20)

NGC 4388

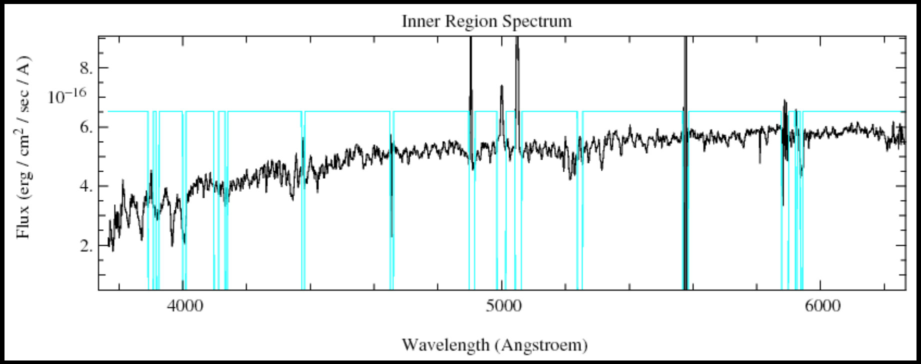
NGC 4388

VLT-FORS

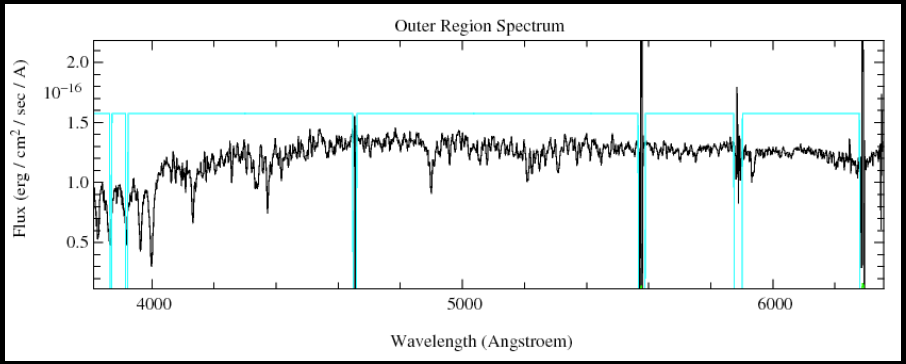




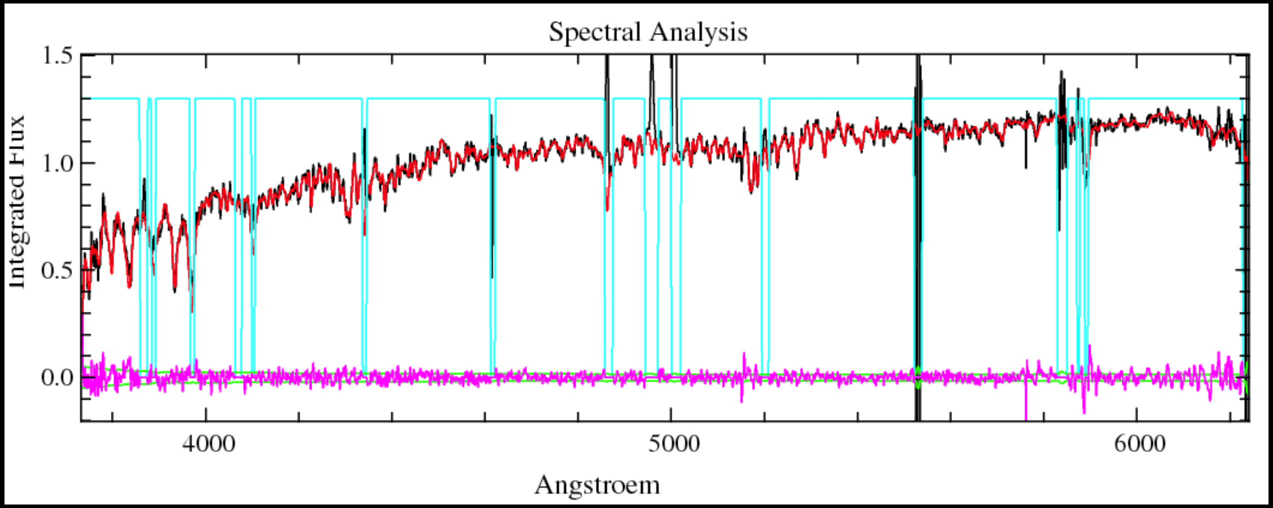
INNER



OUTER

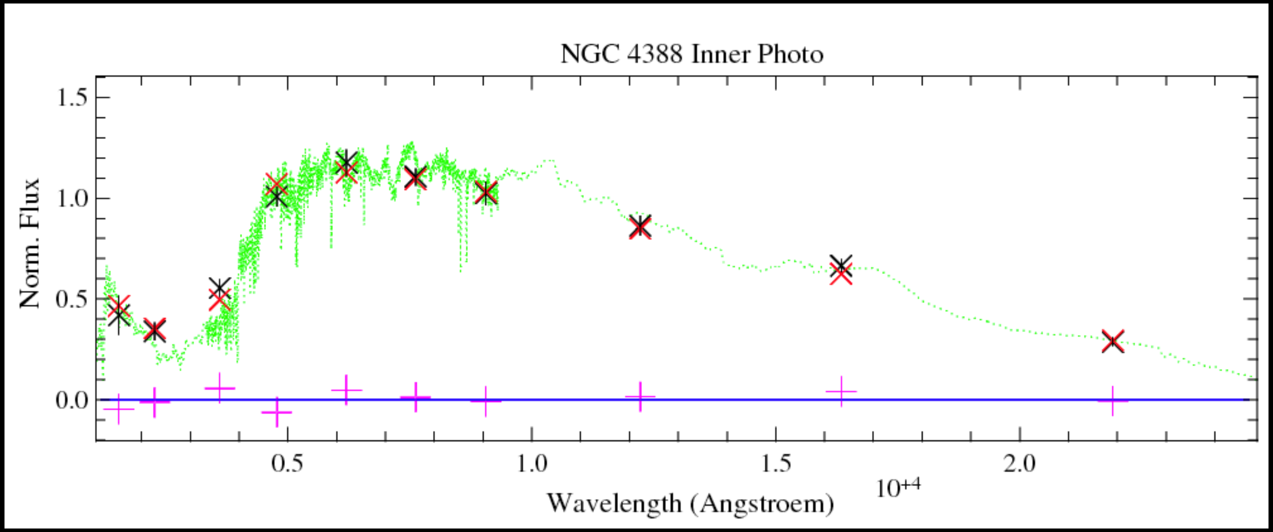


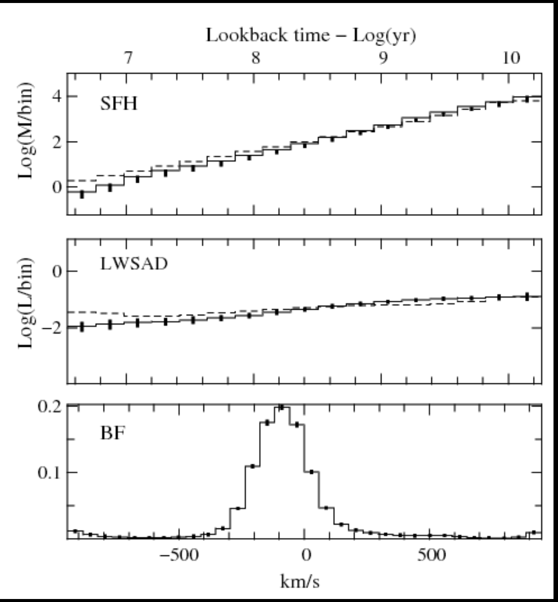
NGC 4388 - Inner Region



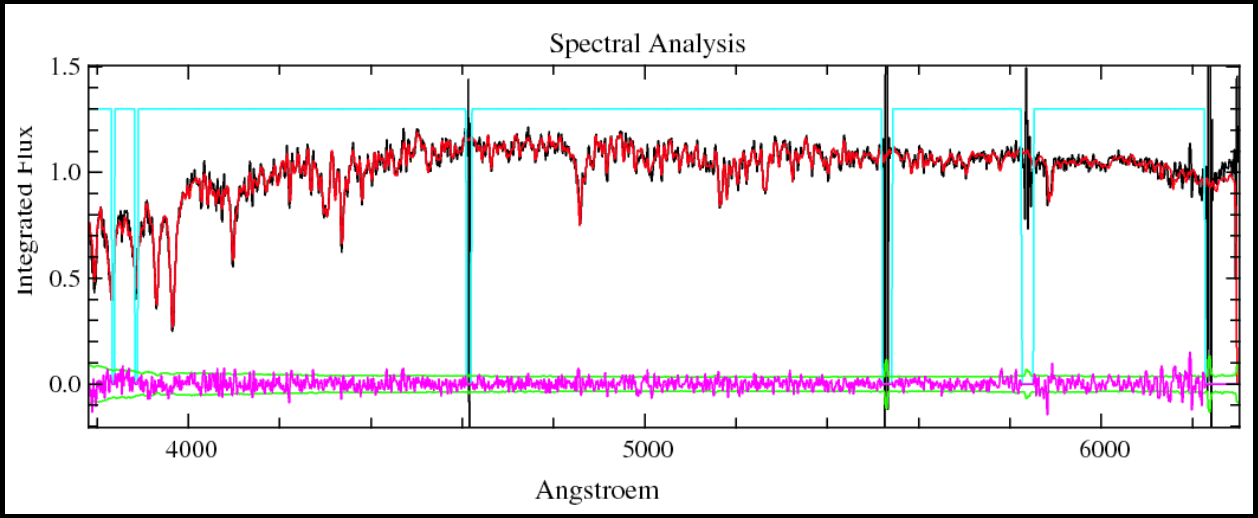
SFH = flat

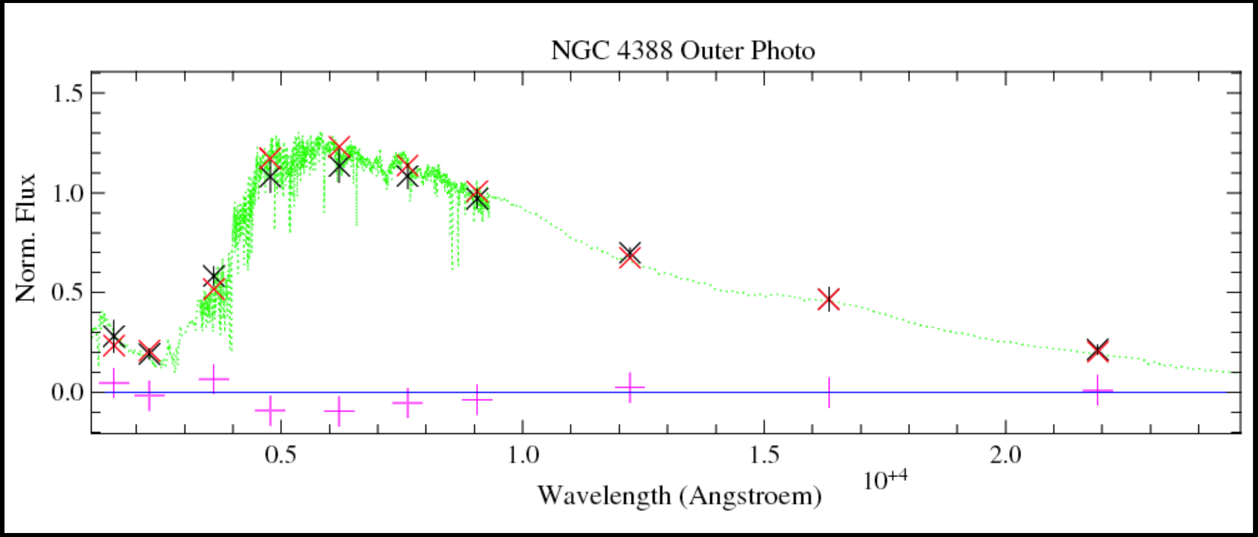
Solar metallicity



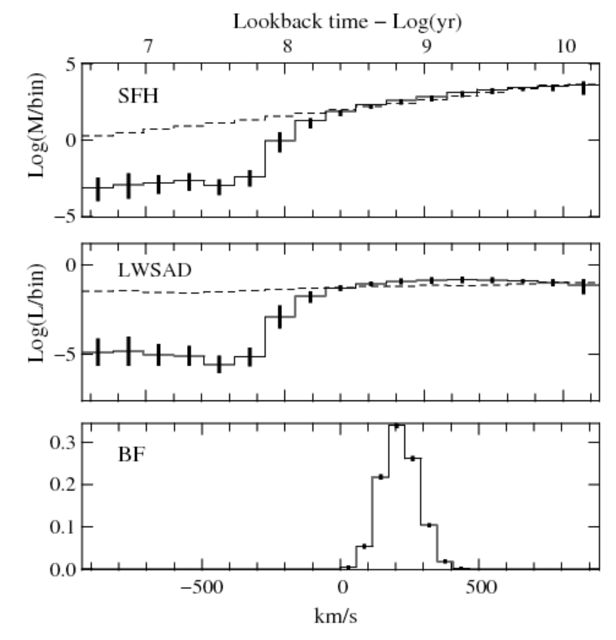


NGC 4388 - Outer Region: NP results



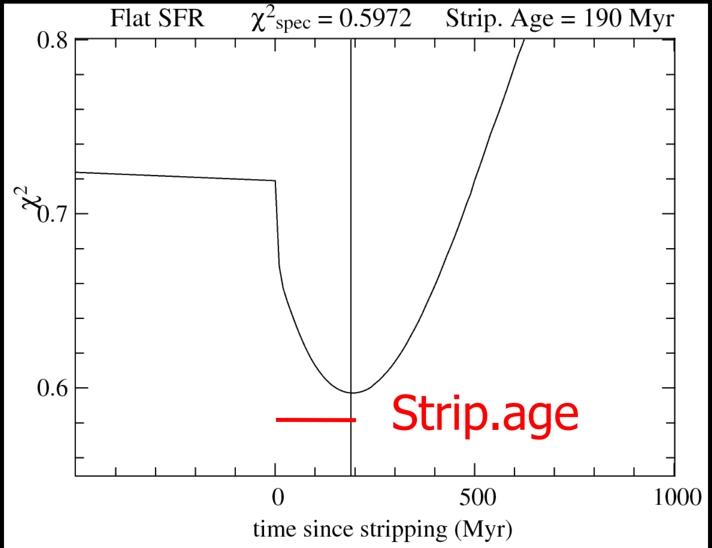


Clear drop in SF

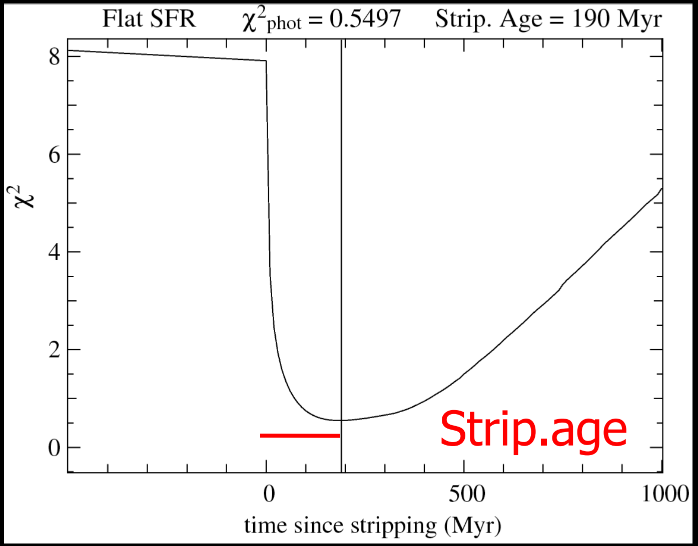


Pappalardo et al. 2010

NGC 4388 - Outer Reg.: Parametric res.

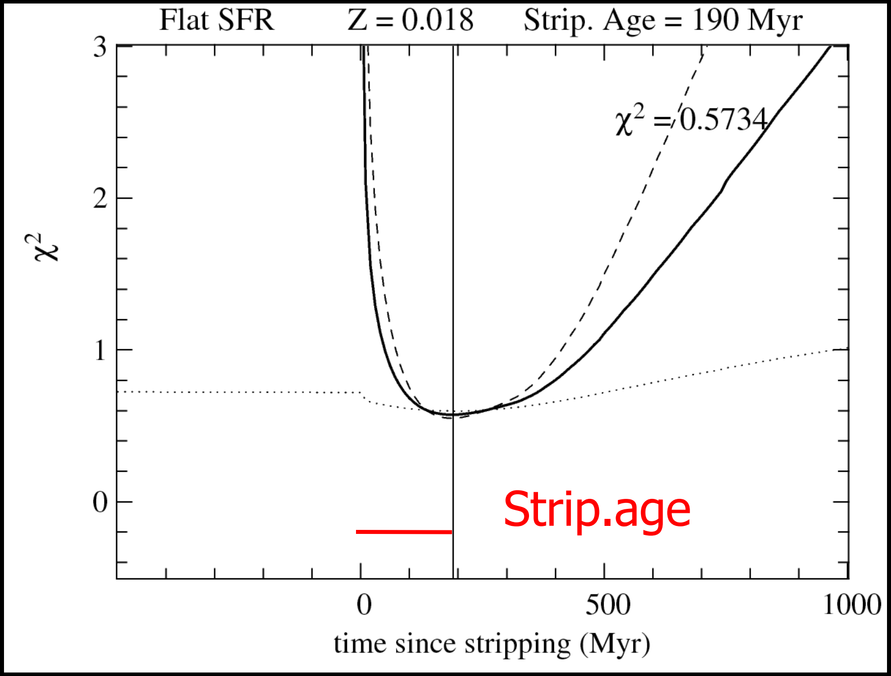


Spectrum



Photo

TOT



Uncertainties in parametric method

A. Star formation models: 5-10 Myr

B. Extinction law: ~ 10 Myr

C. Metallicity value: ~ 10 Myr

D. Monte Carlo simulations: ~ 30 Myr

Conclusions: NGC 4388

The non parametric method:

A. Indicates a constant SFH in the inner region and a recent drop of the SFH in the outer region

B. Recovers a solar metallicity with a small radial gradient

C. Provides constraints on the long term underlying stellar pop.

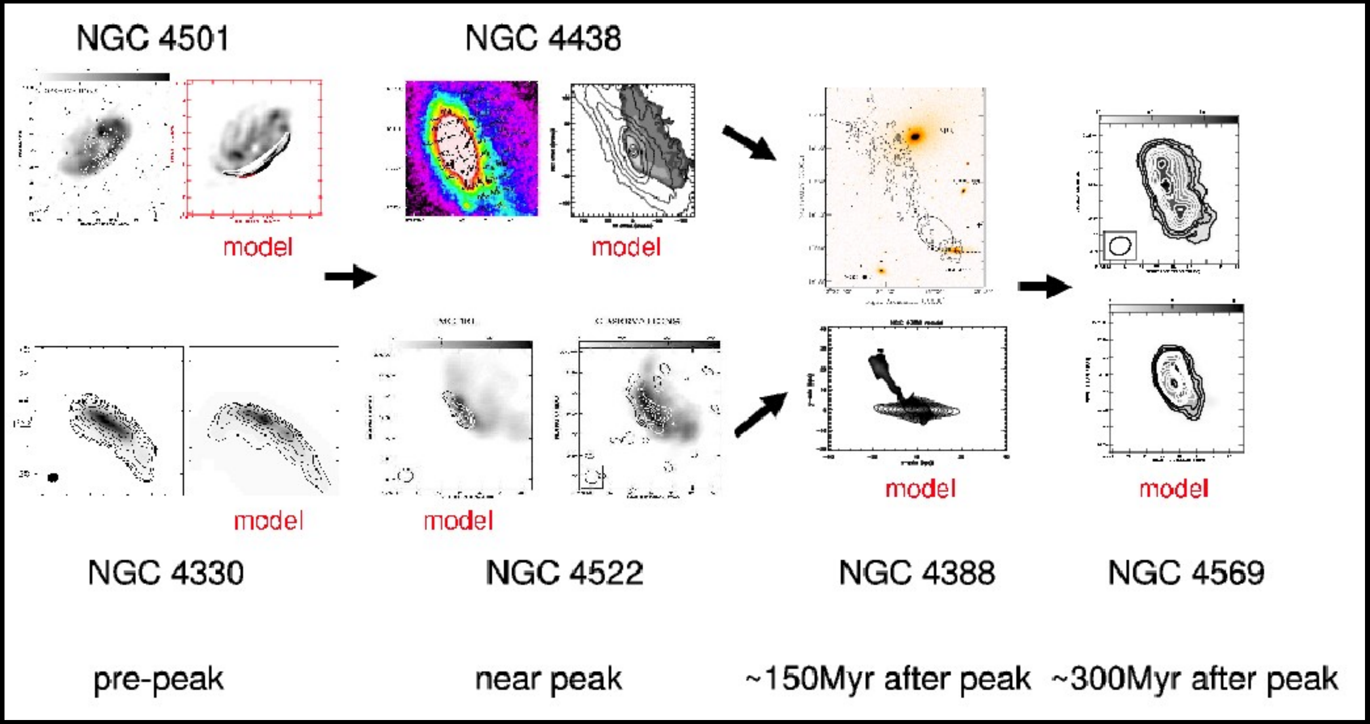
D. Does not provide a sharply truncated SFH

The parametric method:

E. Recovers a stripping age occurred ~190 ± 30 Myr ago, in agreement with revised dyn. models (Vollmer,in prep.)

F. Cannot determine the duration of the stripping event

Outlooks



RPS time sequence

E-ELT instruments:
CODEX and SIMPLE:
R~135000 at wavelengths between
0.37-0.71 micron (CODEX) and 0.8-2.5 micron (SIMPLE)

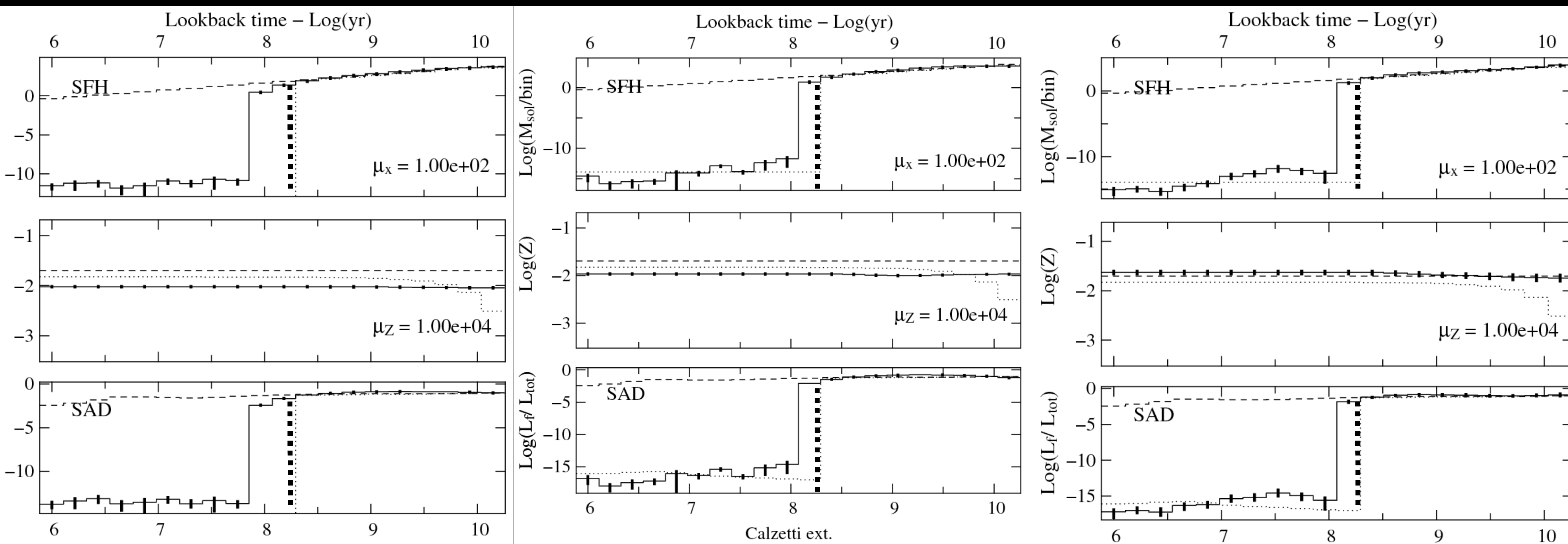
NGC 4580

The End

thanks

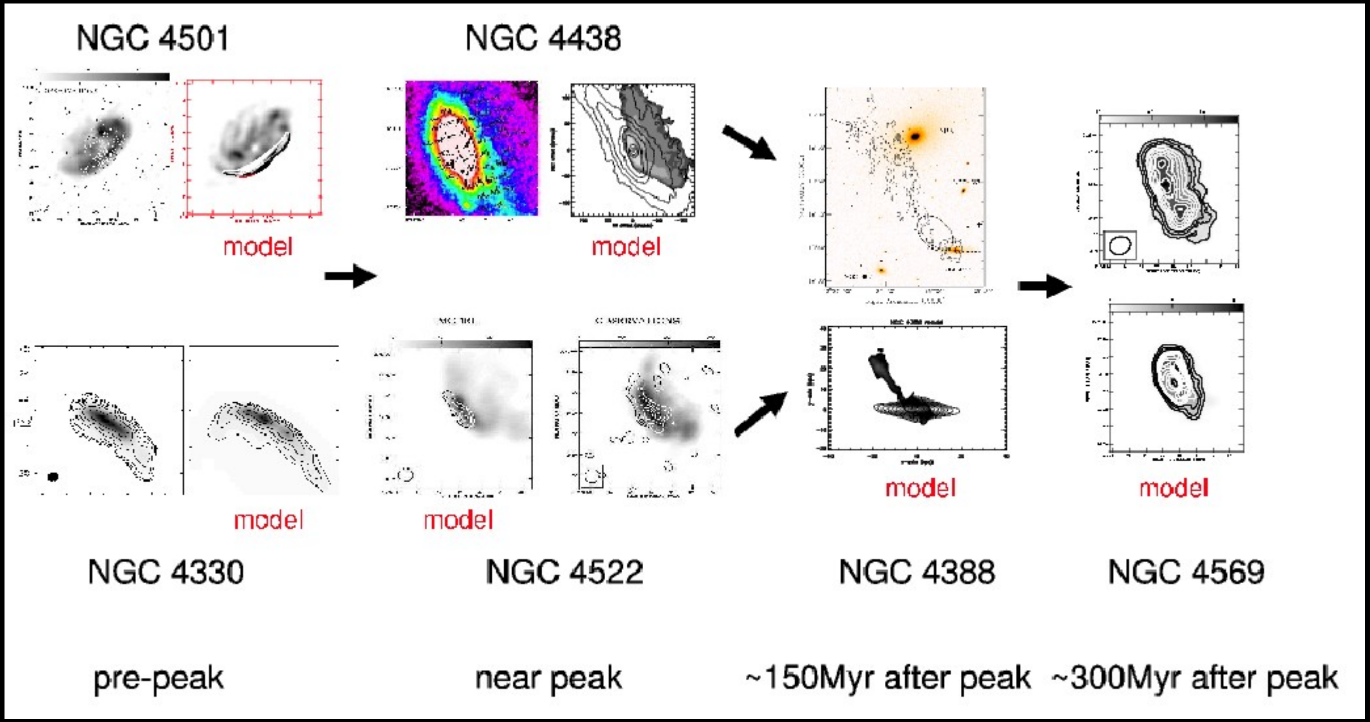
Stripping age

Spectral | Photometric | Combined



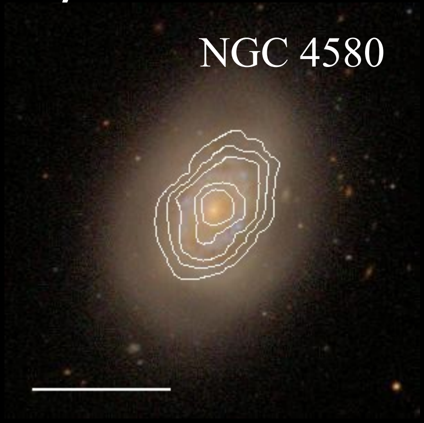
Star formation cut at 130 Myr

Outlooks

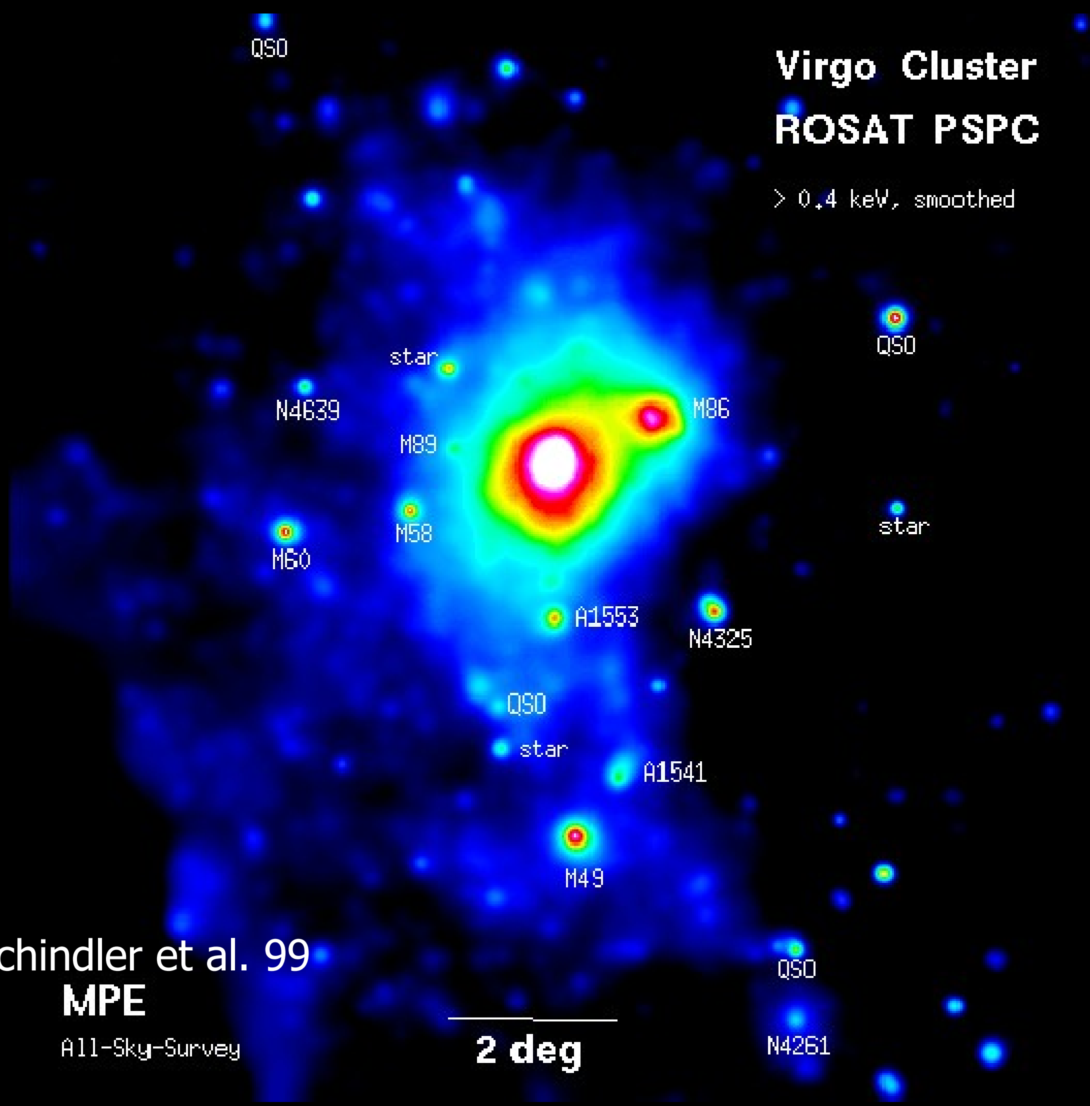


RPS time sequence

HR spectroscopy of the stripped spiral galaxies:
NGC 4501, NGC 4438, NGC 4522, NGC 4330, NGC 4548



Cluster of galaxies



Schindler et al. 99

Clusters:

up to 90 % DM

up to 30 % Hot ICM

few % galaxies

Mass = $10^{14} - 10^{15} M_{\odot}$

Temp ICM = 10 Million K

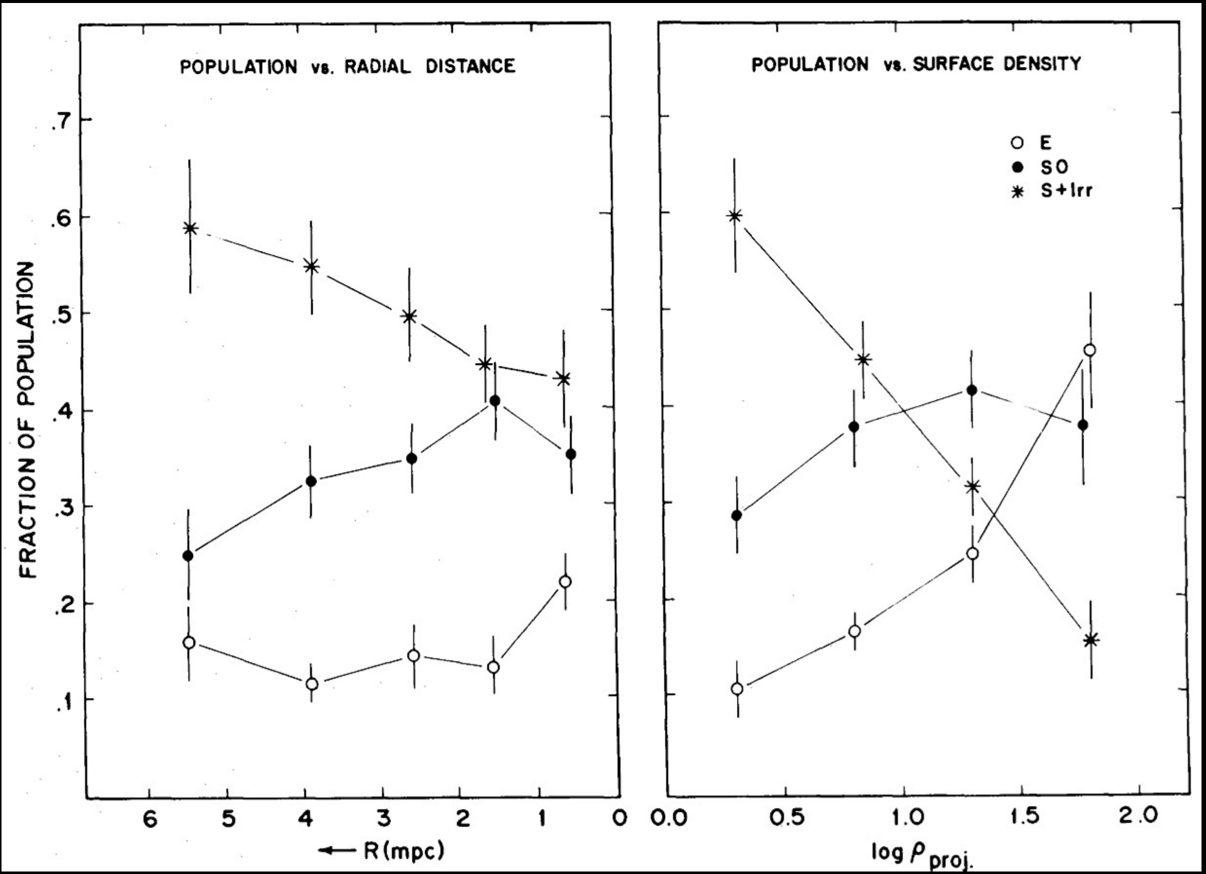
vel. dispersion = 400-700 Km/h

Radius = 1 - 3 Mpc

Cluster galaxies evolution

Observational inferences:

A: Morphology-density relation (Dressler 1980):
early type galaxies increase with the galaxy density and/or clustercentric radius

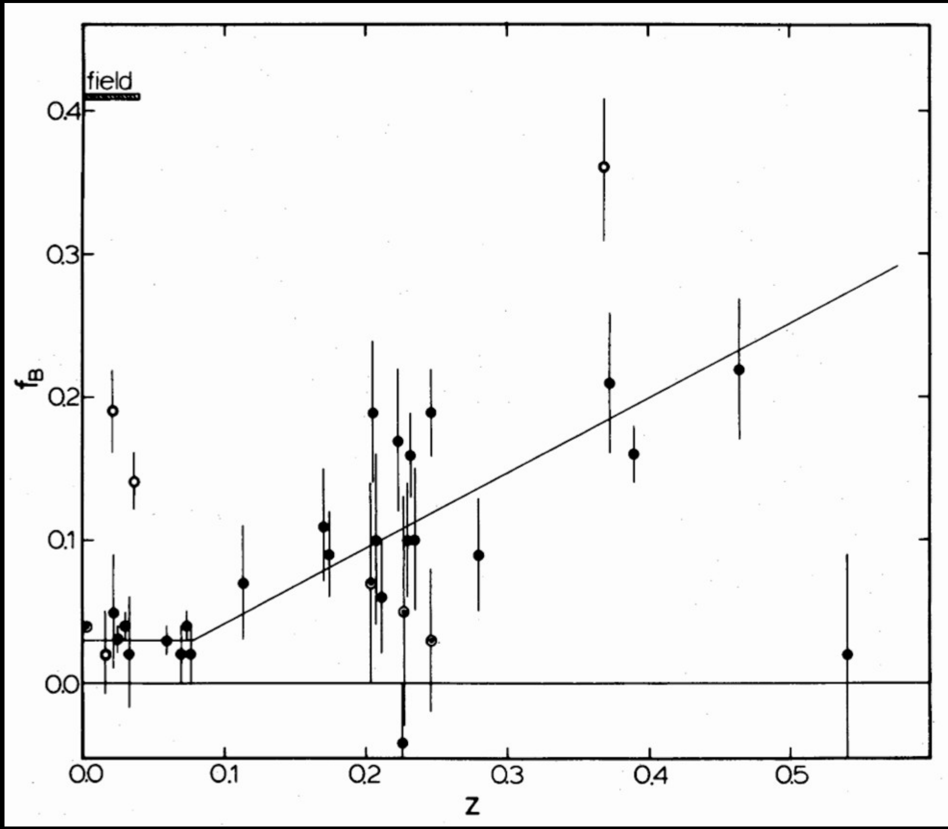


Dressler 1980

Cluster galaxies evolution

Observational inferences:

B: Butcher-Oemler effect (Butcher & Oemler 1978,1984):
cluster at intermediate redshift have higher fraction of blue star forming galaxies

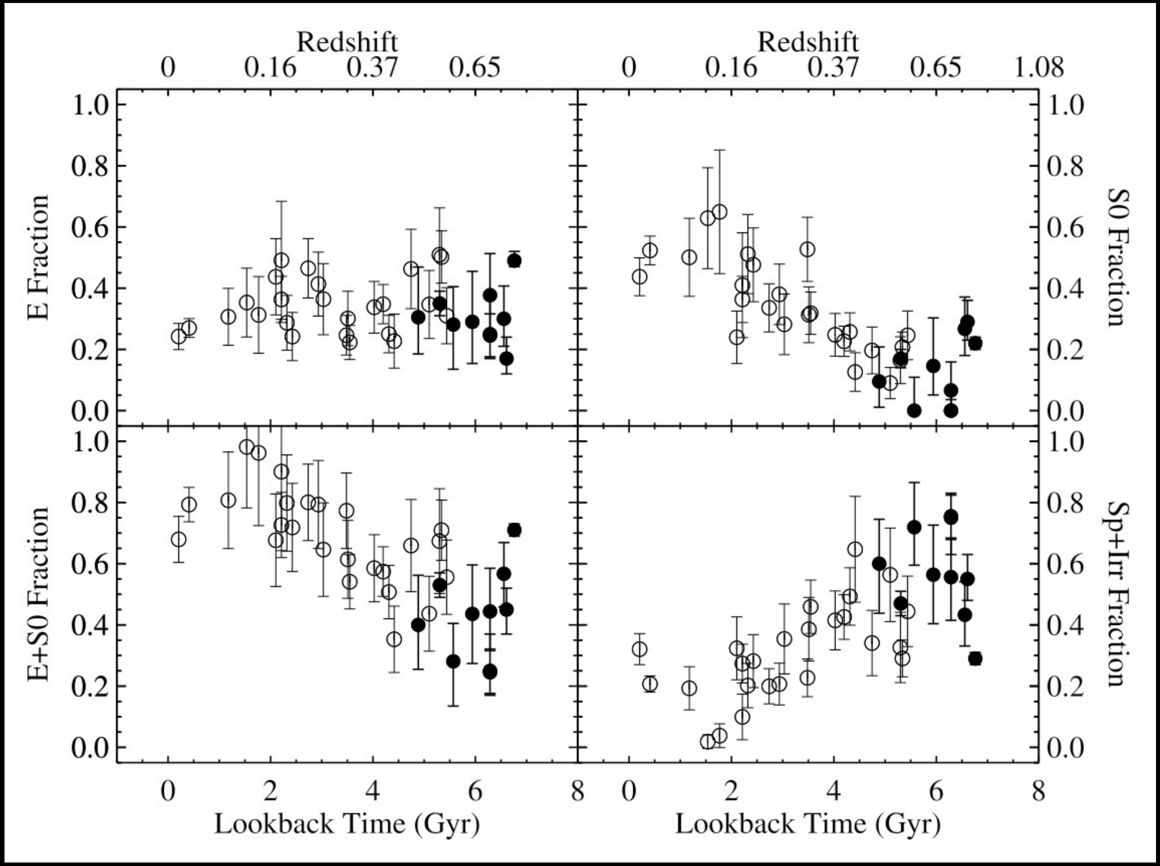


Butcher & Oemler 1984

Cluster galaxies evolution

Observational inferences:

C: Spiral-S0 connection (Dressler 1997):
the number of S0 galaxies decreases at higher redshift, with a proportional increase of spiral fraction



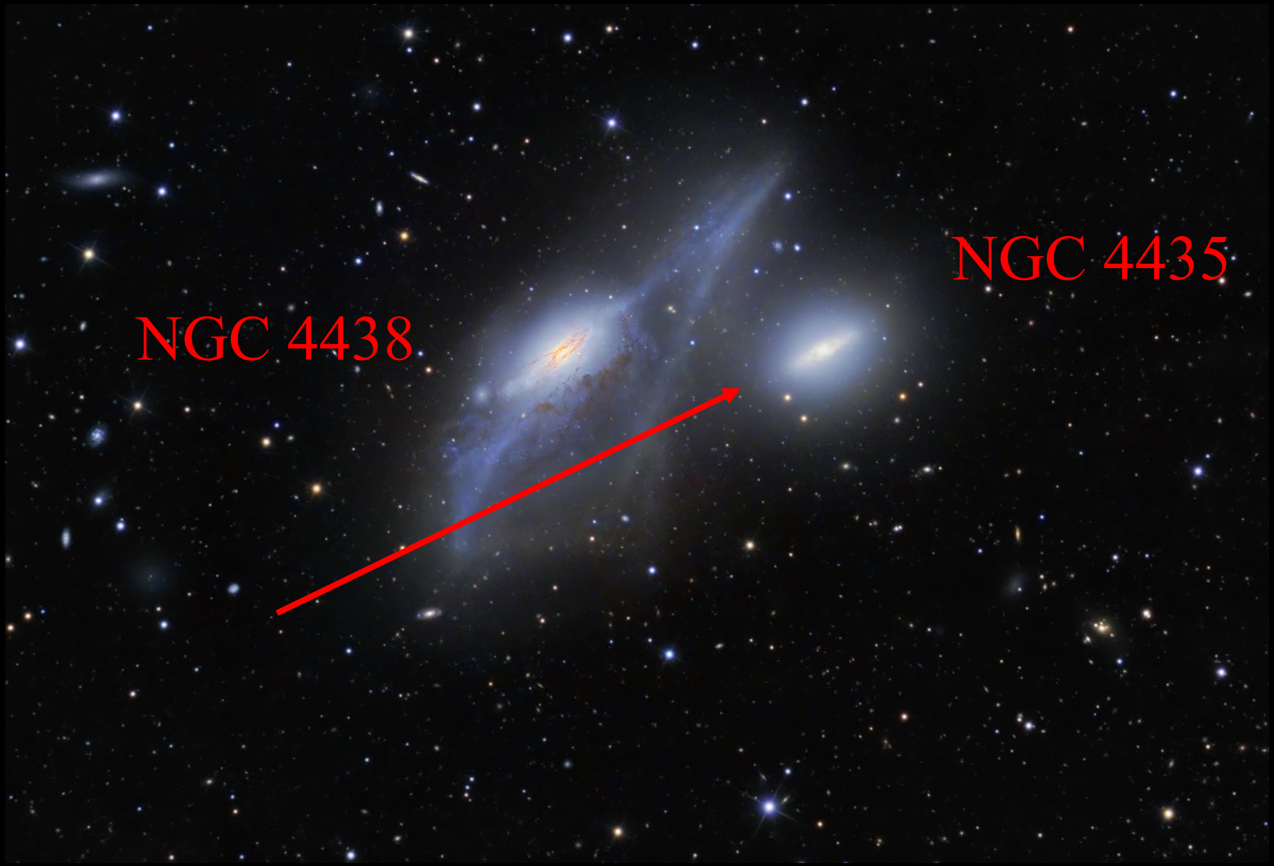
Desai 2007

Cluster galaxies evolution

Physical effects:

A. Gravitational:

tidal interaction (galaxy-galaxy, galaxy-cluster),
harassment



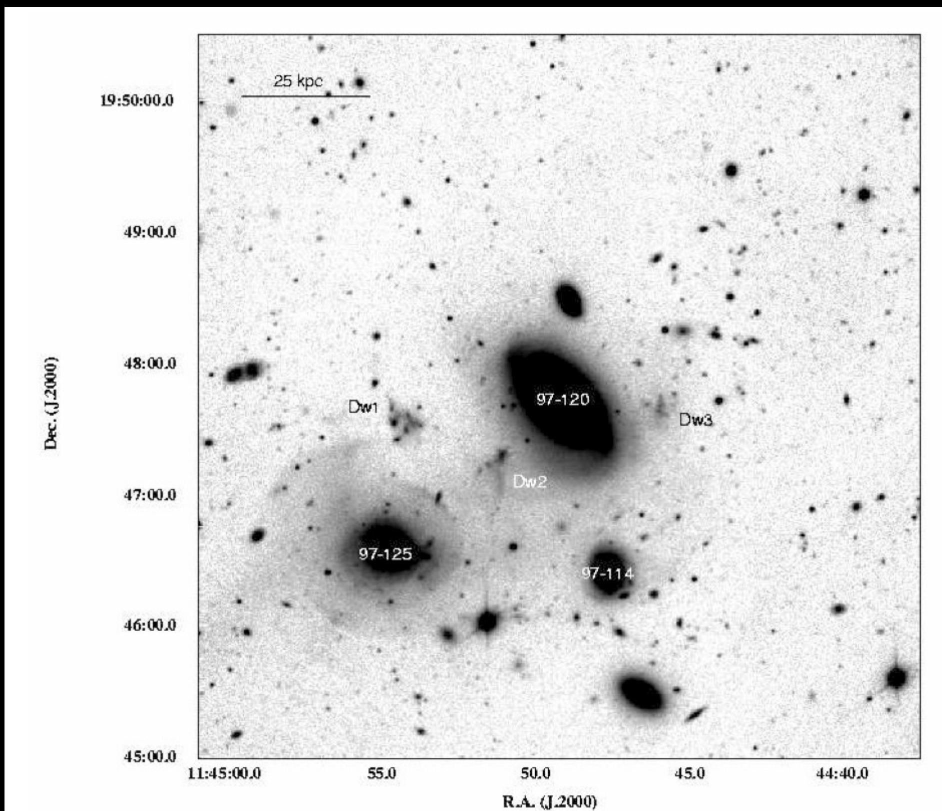
K.Crawford

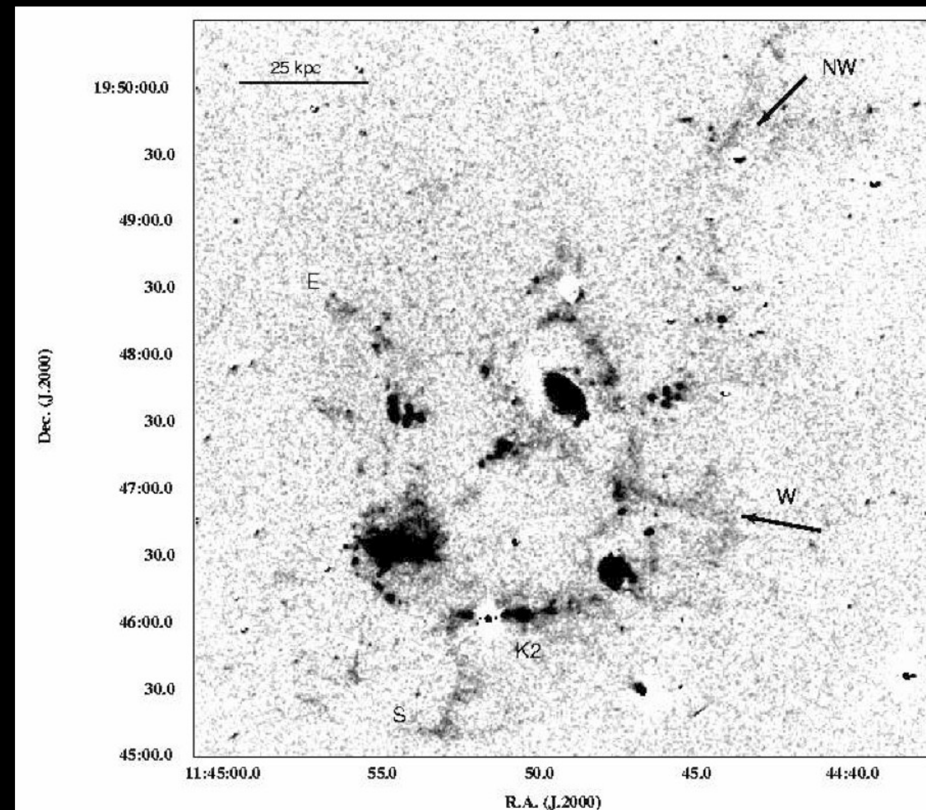
Cluster galaxies evolution

Physical effects:

C. Hybrid processes: preprocessing

Cortese et al.2006





R-band continuum

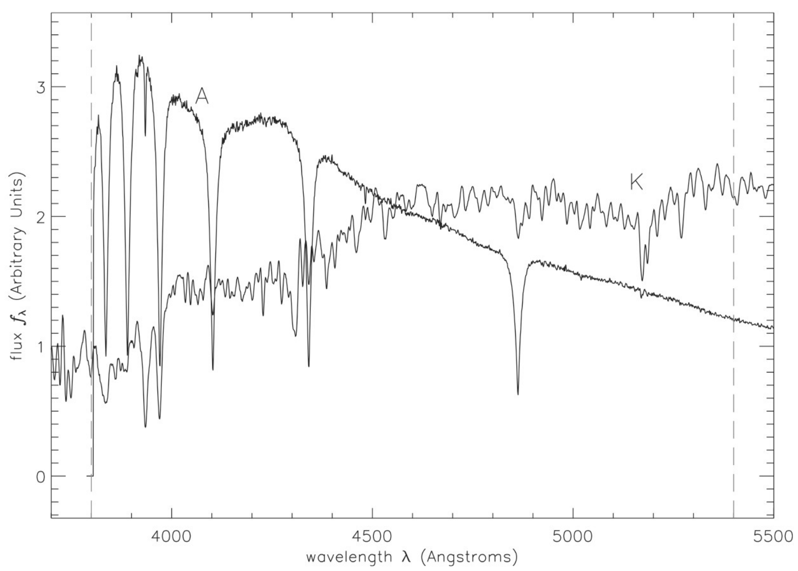
H-alpha

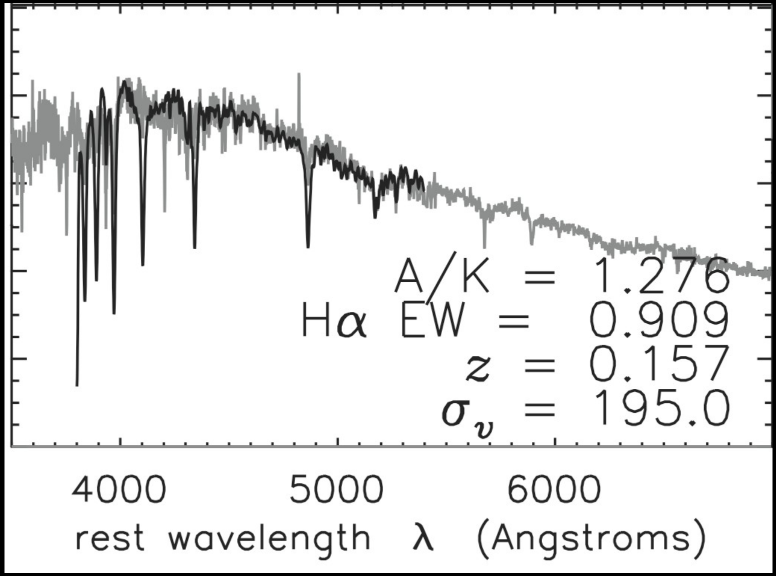
Image of a Blue Infalling Group in Abell 1367

Outlooks

Photometric redshift: estimation of the of the distance of an astronomical object using photometry. Two methods:
A SED fitting
B empirical training set (multiparametric fit)
overcome degeneracies between predicted colours and redshift using Bayesian approach (Benitez 2000)

K+A galaxies = Absorption lines of A-stars but little sign of current SF (dramatic events in the last Gyr).

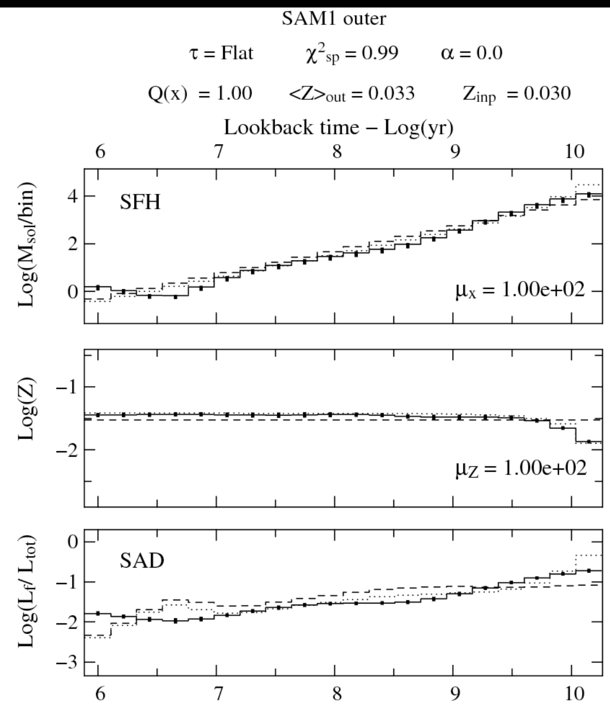


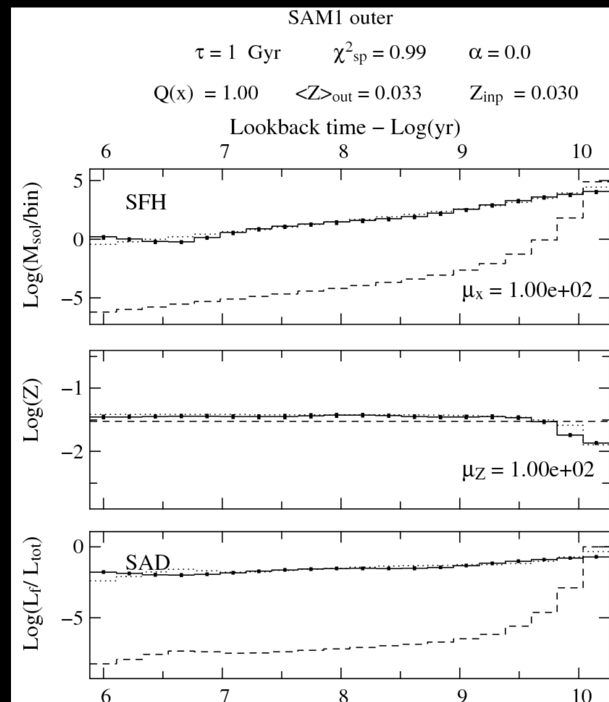


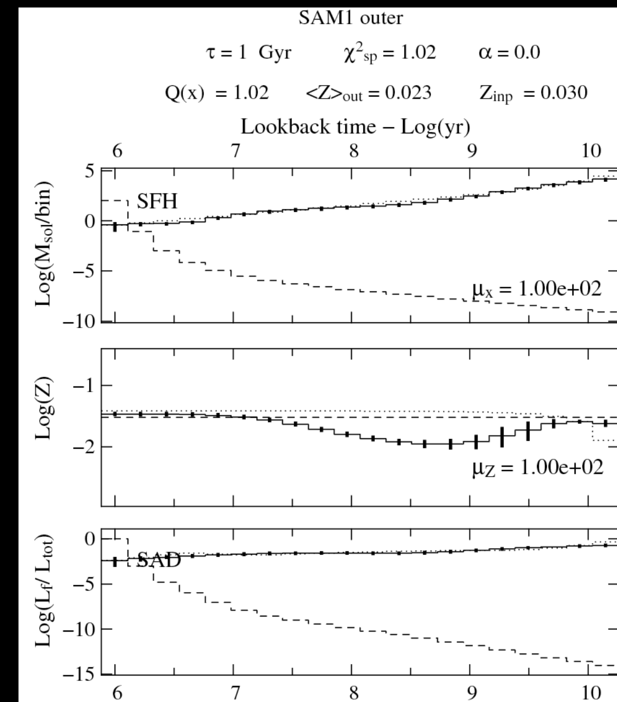
Quintero et al. 2004

Initial guess

Influence of initial guess in the results







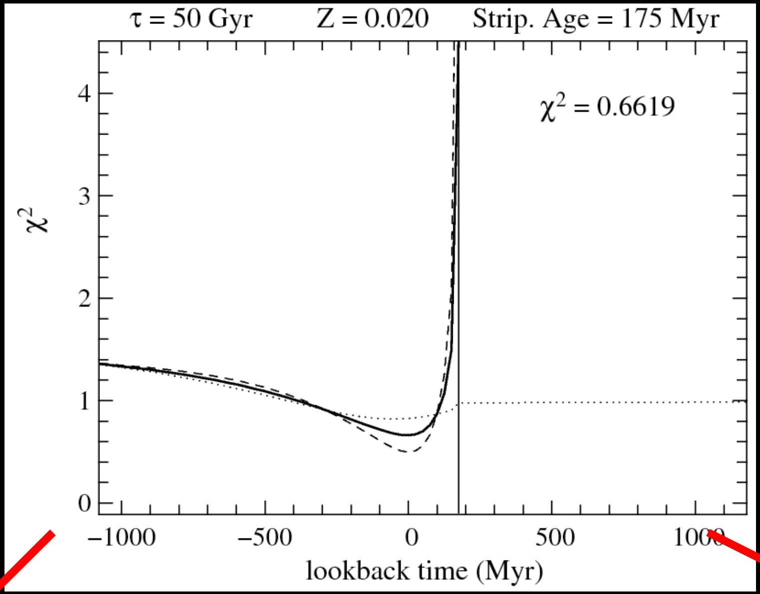
I.C. = Flat
Star Formation

I.C. = decreasing
Star Formation
with tau = 1 Gyr

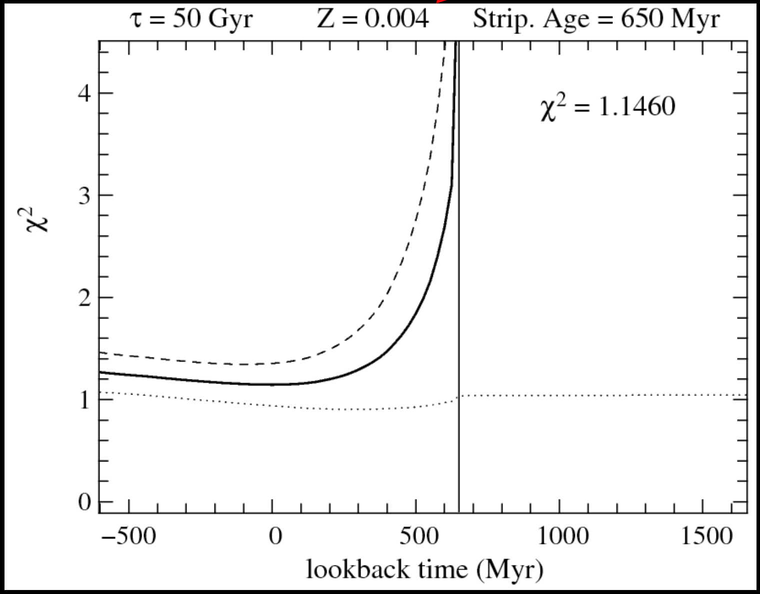
I.C. = increasing
Star Formation
with tau = 1 Gyr

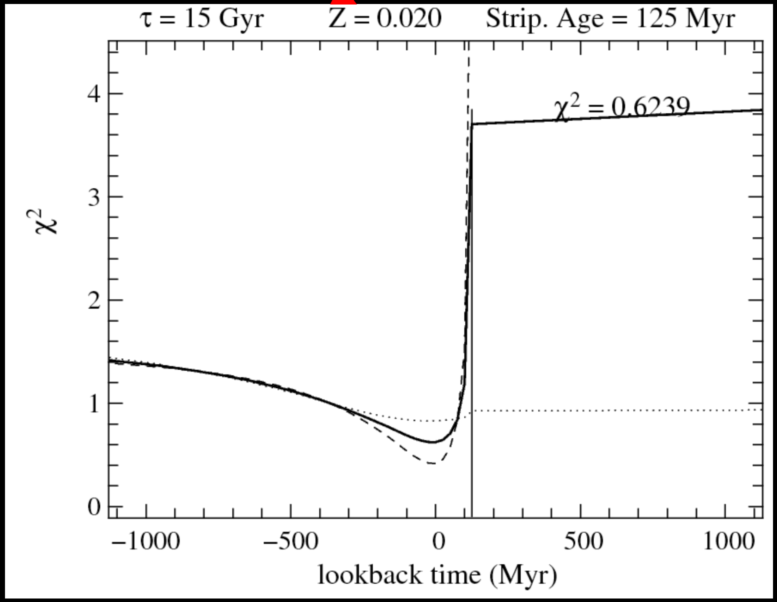
Influence of timescale and met. value

metallicity
stripping age



exp timescale
stripping age





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