Kinematic and stellar population gradients as fingerprints of past merger in elliptical galaxies

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Structural properties of E galaxies are related to their Luminosity (Kormendy & Bender 1996) :

More Luminous (MB<-20), slowly rotating , boxy isophotes, core inner profile, large amount minor axis rotation.

Less luminous (MB>-20), rapid rotator , disky isophotes , power law inner profile, very little minor axis rotation.

Mergers with and without dissipation can explain these properties (Barnes & Hernquist 1996, Faber et al. 1997, Khochfar & Burkert 2005, Naab et al. 2006b, Graham 2004) :
This could also explain the tilt of the FP (Oñorbe et al. 2005), and put into agreement the hierarchical scenarios with the derived SFH for galaxies (e.g. de Lucia et al 2004)...

Interaction with and without dissipation leads to different stellar population gradients:

* Dissipation: stronger metallicity gradients, a correlation between [Z/H] gradient and mass (Bekki & Shioya 1999),.

* No dissipation: shallower metallicity gradients, pure stellar mergers tend to wipe out the original gradient in the galaxy, but not completely

(White 1980). If the growing of structure is hierarchical it could be an anti-correlation between [Z/H] gradients and mass.

Relation between SP gradients and other structural properties of galaxies

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Galactic winds : (Franx & Illinworth 1985):

Negative metallicity gradient . Positive [α/Fe]. Correlation between metallicity and [α/Fe] gradients.

The sample

- ✓ 11 early-type galaxies (10 E 1 S0) covering a wide range in luminosity
- ✓ Observed with Keck (S/N in the external bins (at ≈ 1 - 3 r_{eff}) of 55 per Å)

Currently reducing 7 more galaxies

Derivation of Stellar population parameters

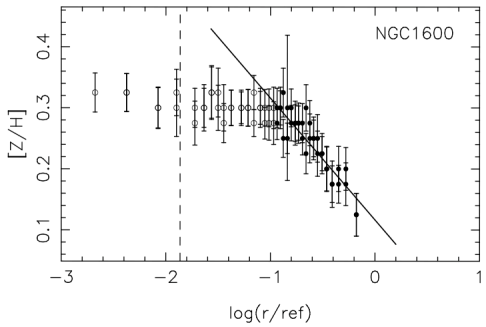
χ^2-minimization with 11 Lick/IDS indices using TMB03.

Comparison with other techniques and models

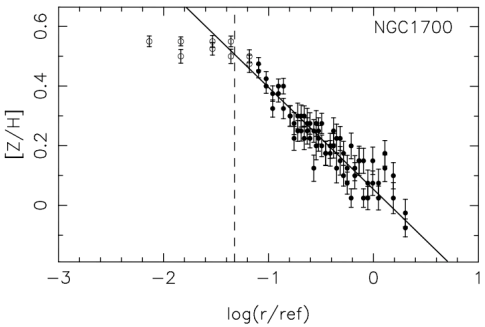
Fit 3 indices, different partitions of [E/Fe], Vazdekis et al. 2007 and BC03 with Trager et al. (2000) method ...

Metallicity gradients

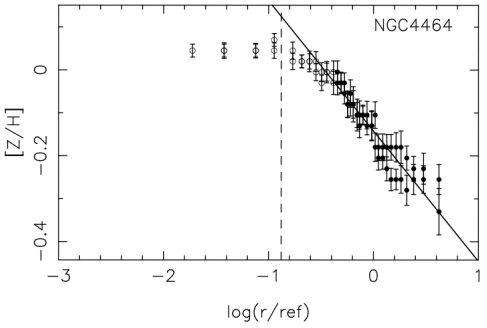
-0.193±0.024



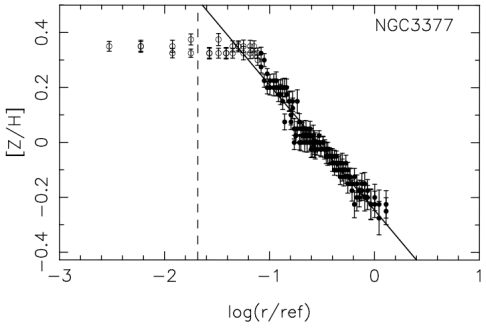
-0.342±0.024



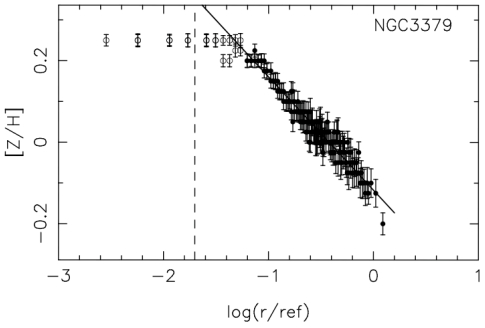
-0.306±0.017



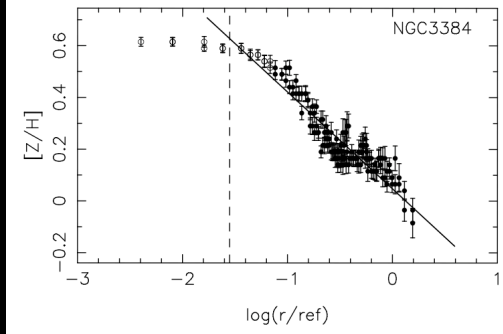
-0.466±0.009



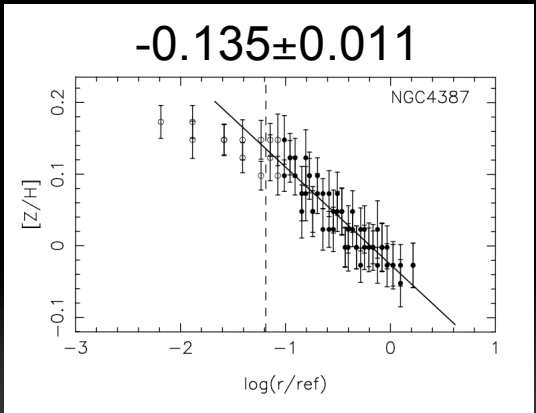
-0.278±0.006

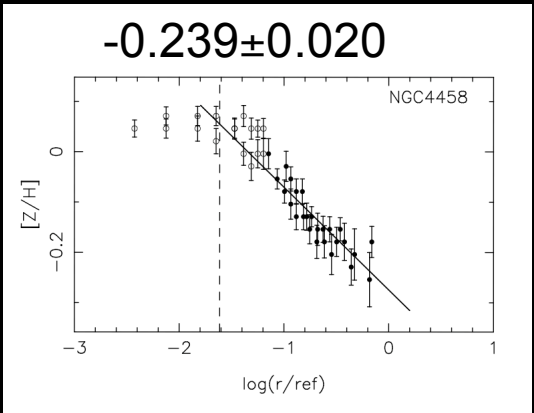


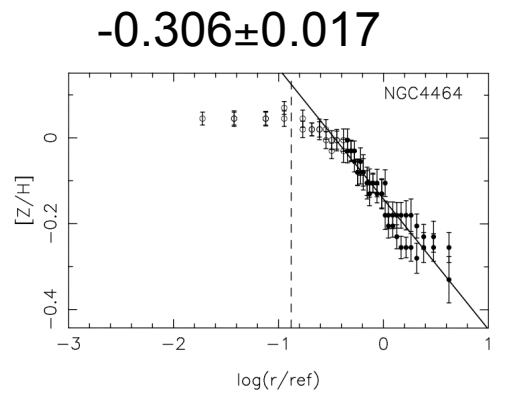
-0.381±0.008

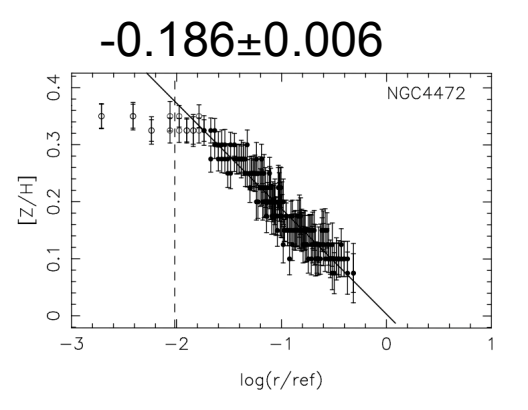


Metallicity gradients



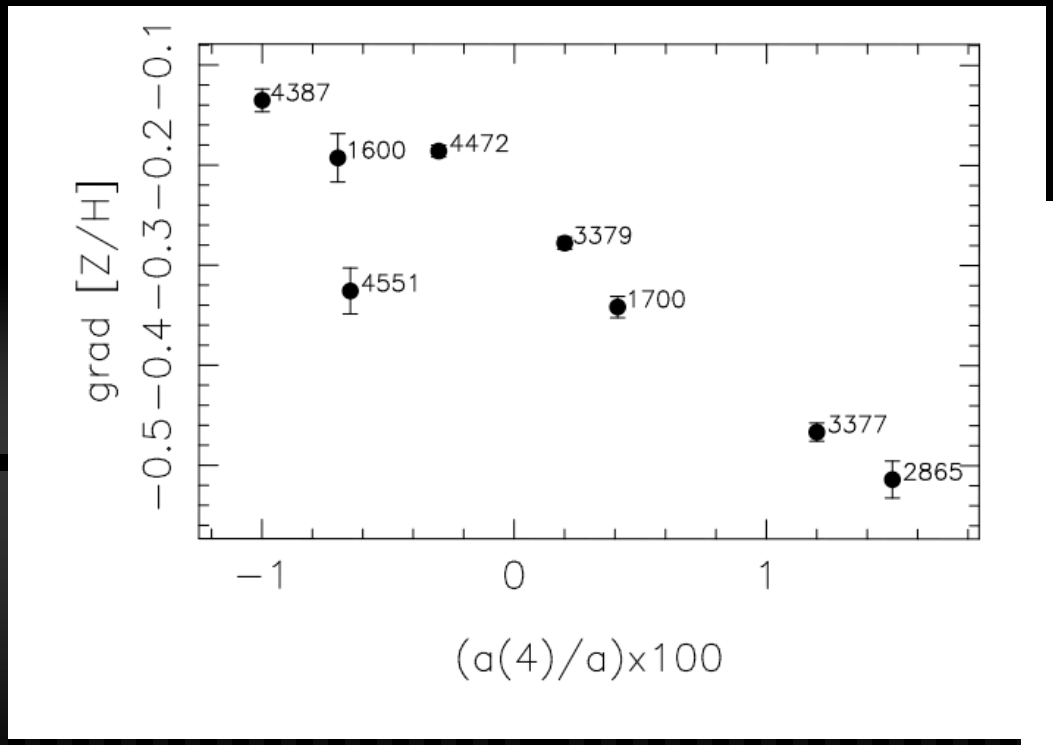


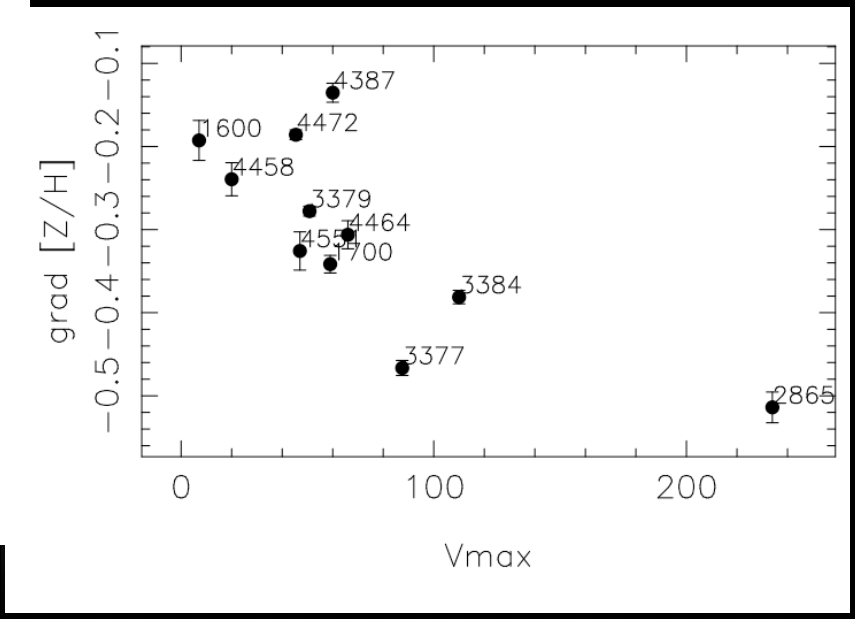




Mean grad[Z/H]=-0.306
rms=0.133
Compatible with other studies

Metallicity gradient vs. isophote shape

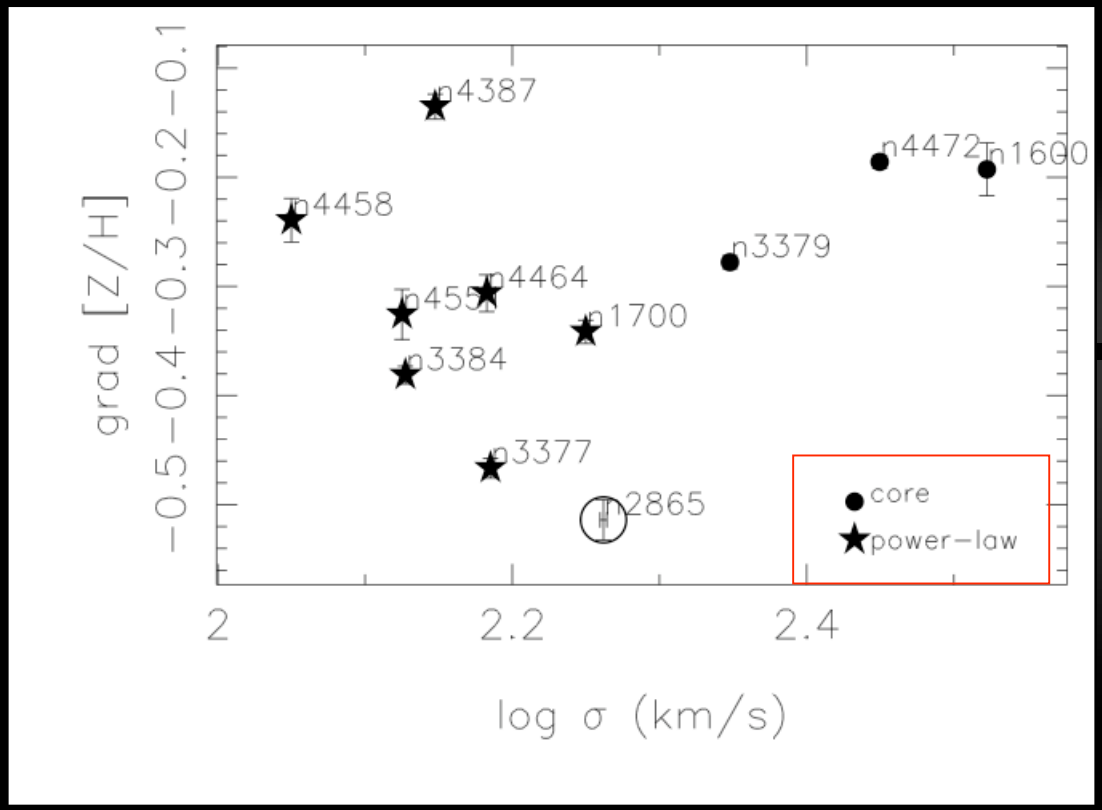




a4

Dissipation during the interaction (Bekki & Shioya 1999,Naab & Burkert 2003; Khochfar & Burkert 2005)

Grad [Z/H] vs. central σ



Colors gradients and line-strength gradients are steeper in ETG with:

$M \approx 10^{11} M_{\odot}$

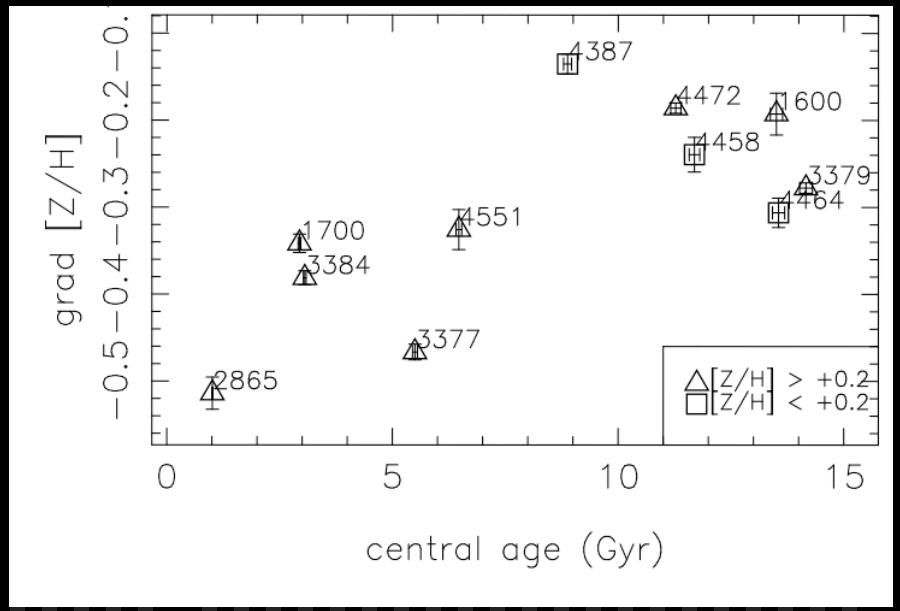
$\sigma \approx 200$ km/s

$M_B \approx -20.5 - 21.5$

(Vader 1988; Carollo et al. 1993; Kormendy & Djorgovski 1989)

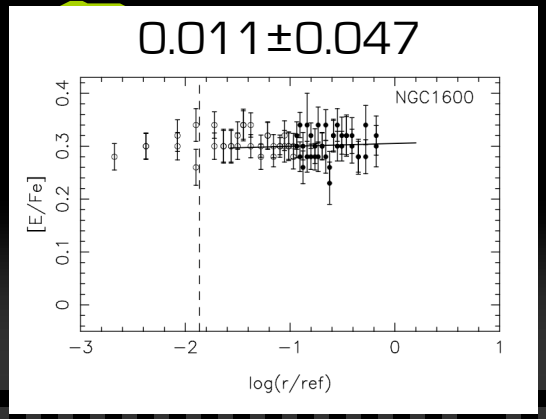
- Transition between dry/and wet mergers? (Faber et al. 2005) Schawinski et al. 2006

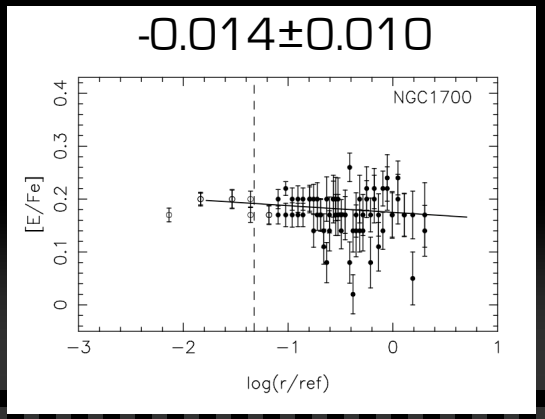
Correlation of gradients with other parameters

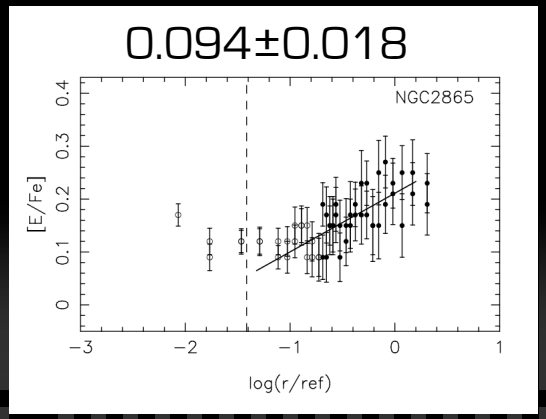


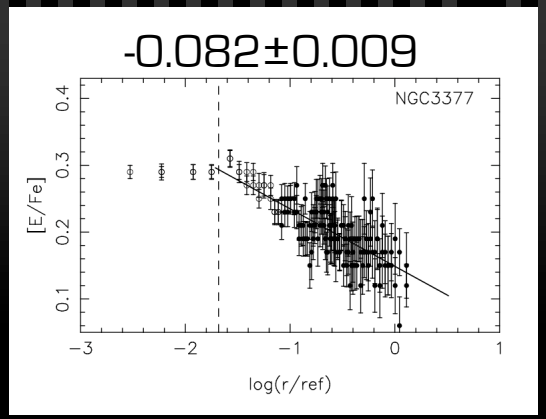
This supports the idea that the "recent" episode of star formation detected in some ETGs has been triggered by interactions.

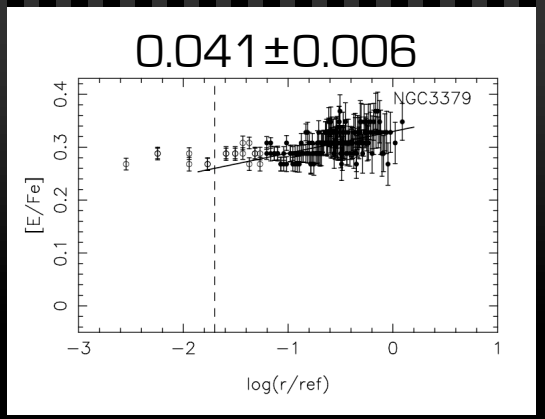
[E/Fe] gradients

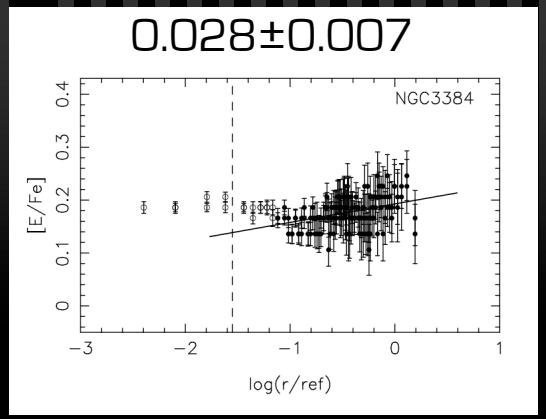






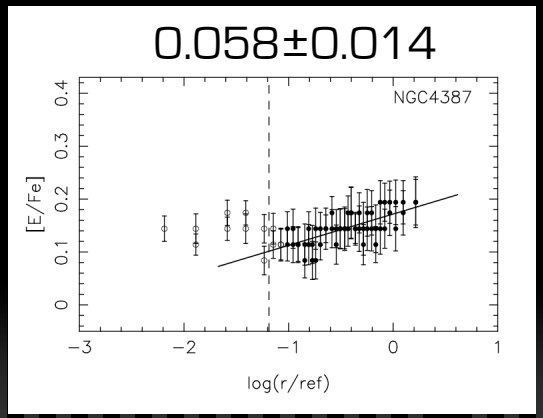


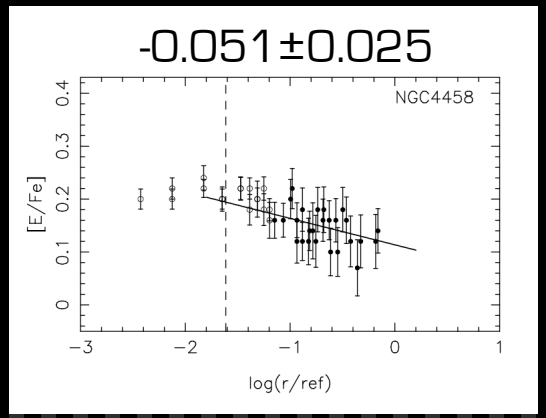


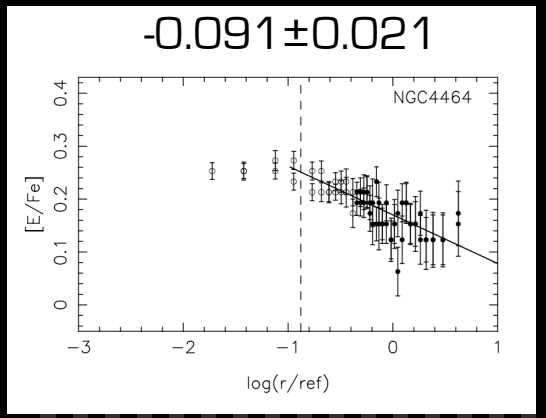


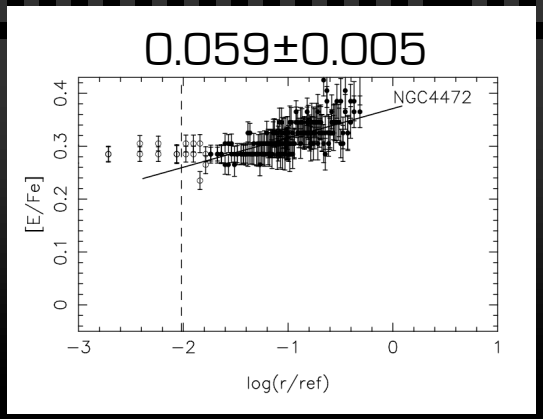
Enhanced: O, Ne, Mg, Si, S, Ar, Ca, Ti, N, Na

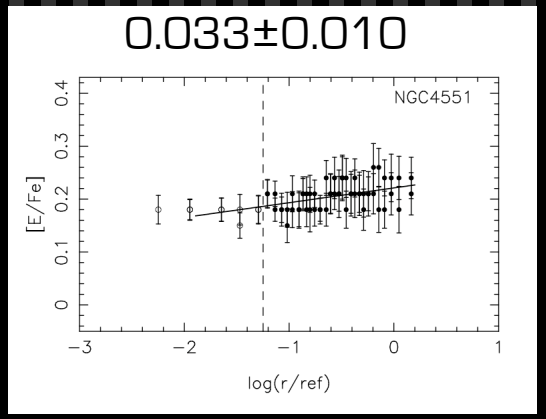
[E/Fe] gradients





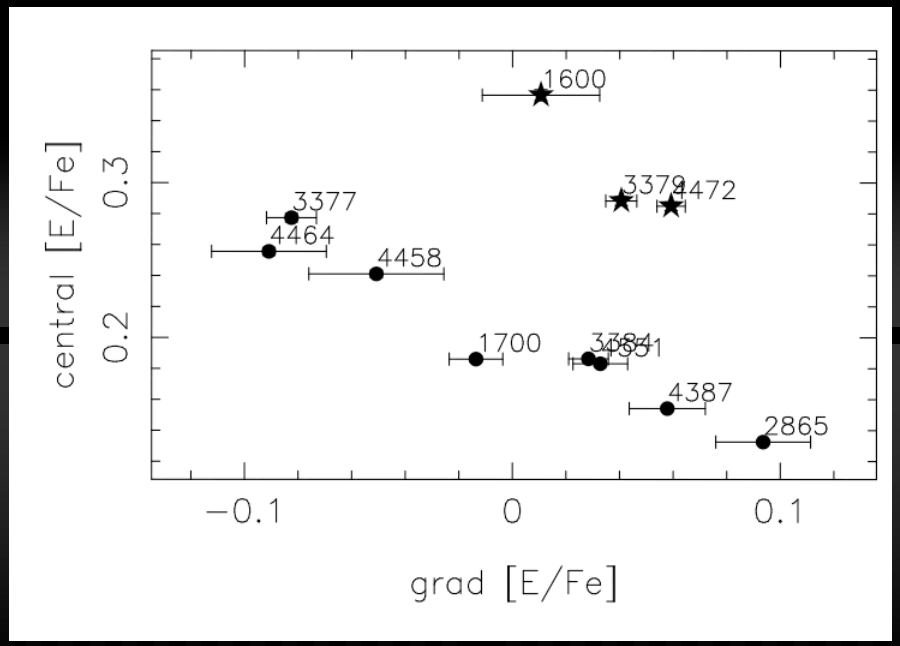






- Simple outside-in scenarios are not valid for all our galaxies
- Duration of SF is not the only parameter controlling gradients. Rule out galactic winds as the only mechanism to form SP gradients

Grad [E/Fe] vs. central [E/Fe]

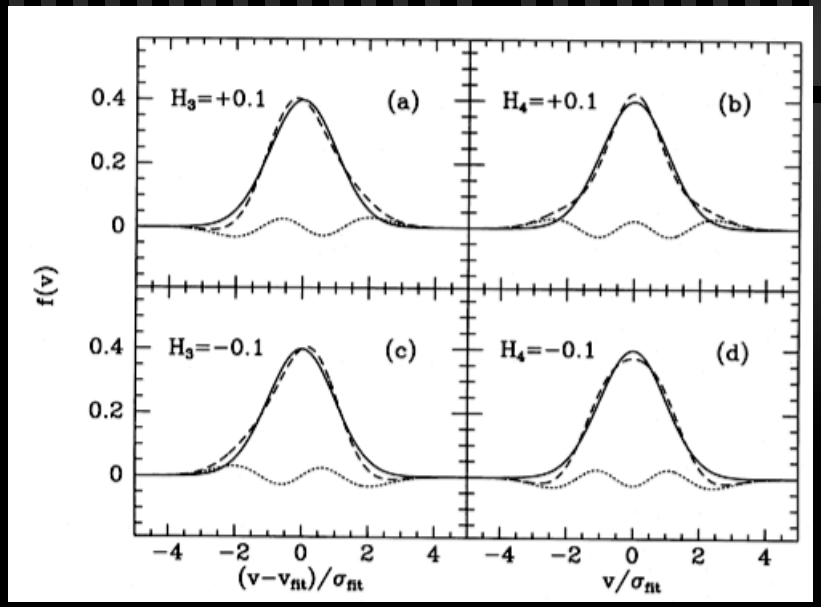


- ● $\sigma < 200$ kms^{-1}, power-law
- ★ $\sigma > 200$ kms^{-1}, core

More data needed,
but it seems to exist a
fundamental difference.

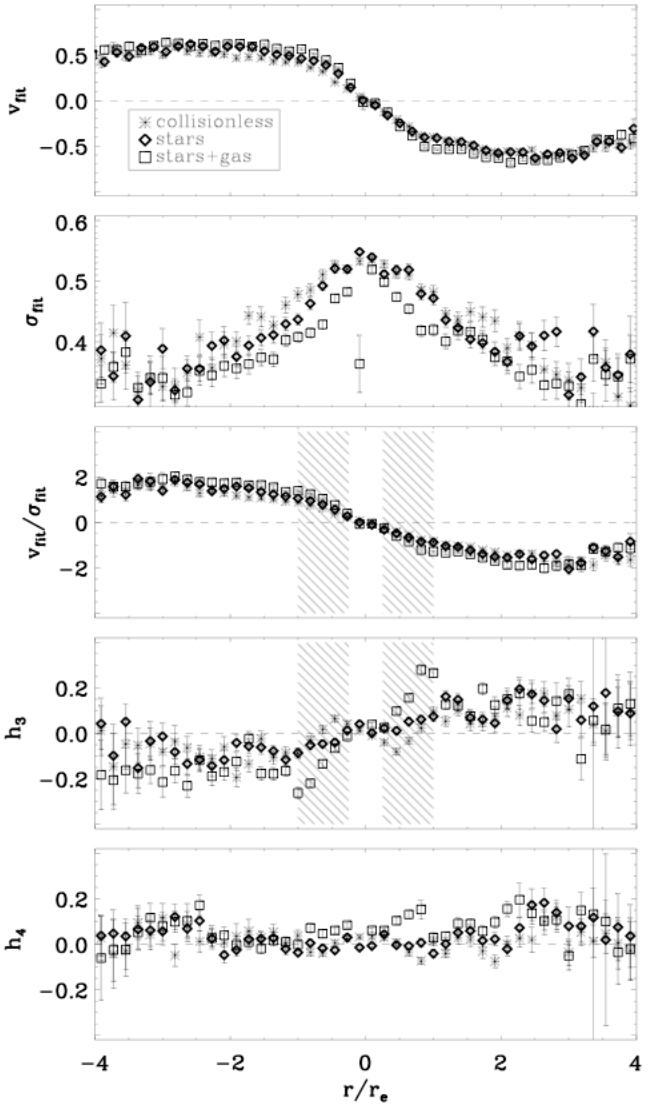
N-body/SPH simulations

Naab, Jesseit & Burkert 2006



Bender et al. 1994

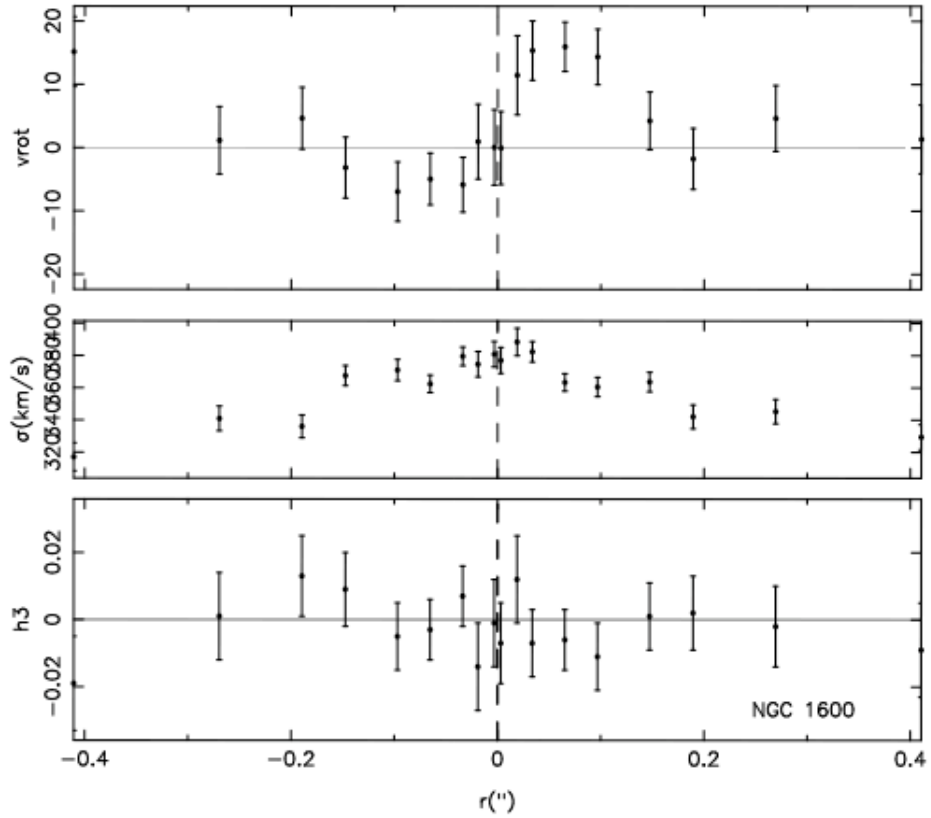
3:1 remnant



SFH along the radius

STECMAP (Ocvirk et al. 2006a,b)
(STEllar Content via Maximum A Posteriori)
-non-parametric method
http://astro.u-strasbg.fr/obs/GALAXIES/stecmap_eng.html

Vazdekis et al. (2007) (MILES) (3500-5100 Å)

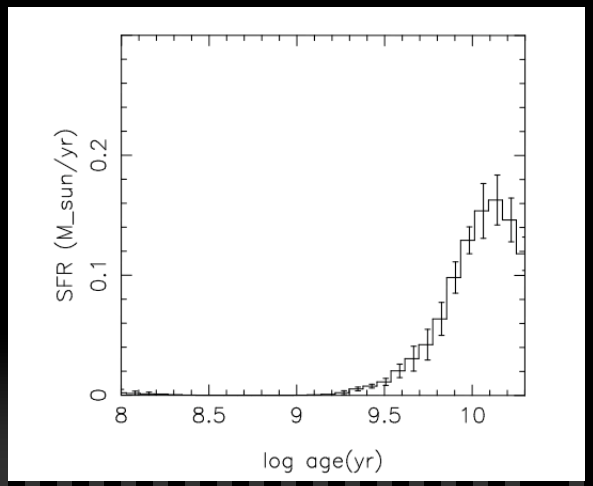


NGC 1600
field
σ = 333.0±2.0 km/s
Core inner profile

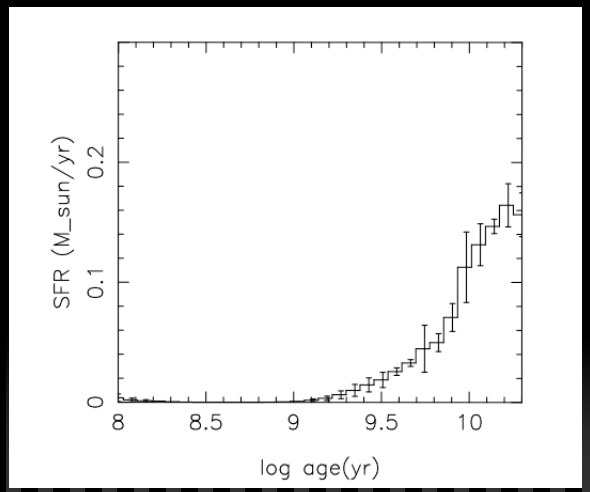
Boxy isophotes

Very little rotation
Small h3 parameter
Central age = 13.5 Gyr

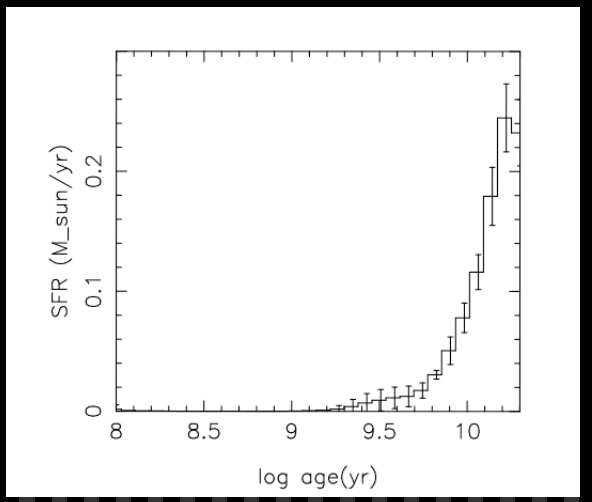
SFH NGC1600



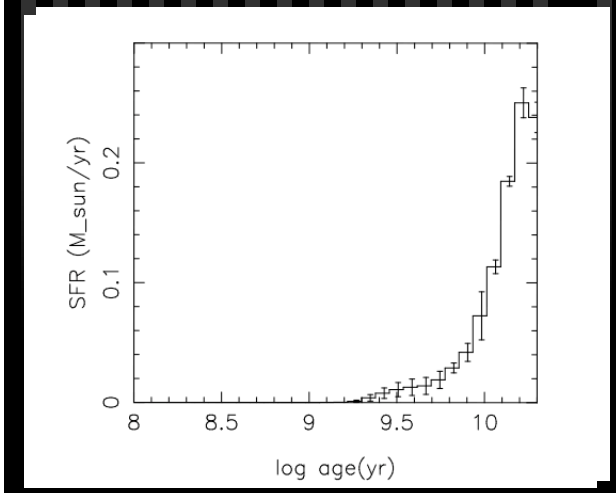
r=19.5”

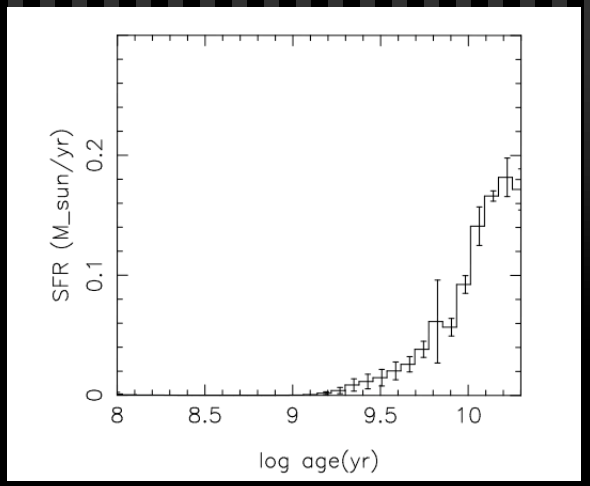


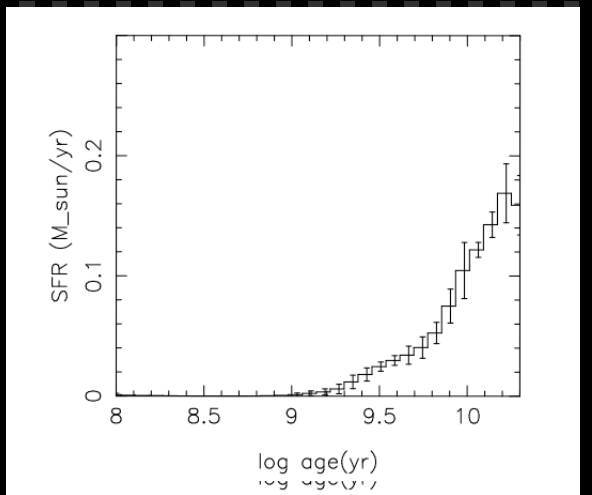
r=7.0”

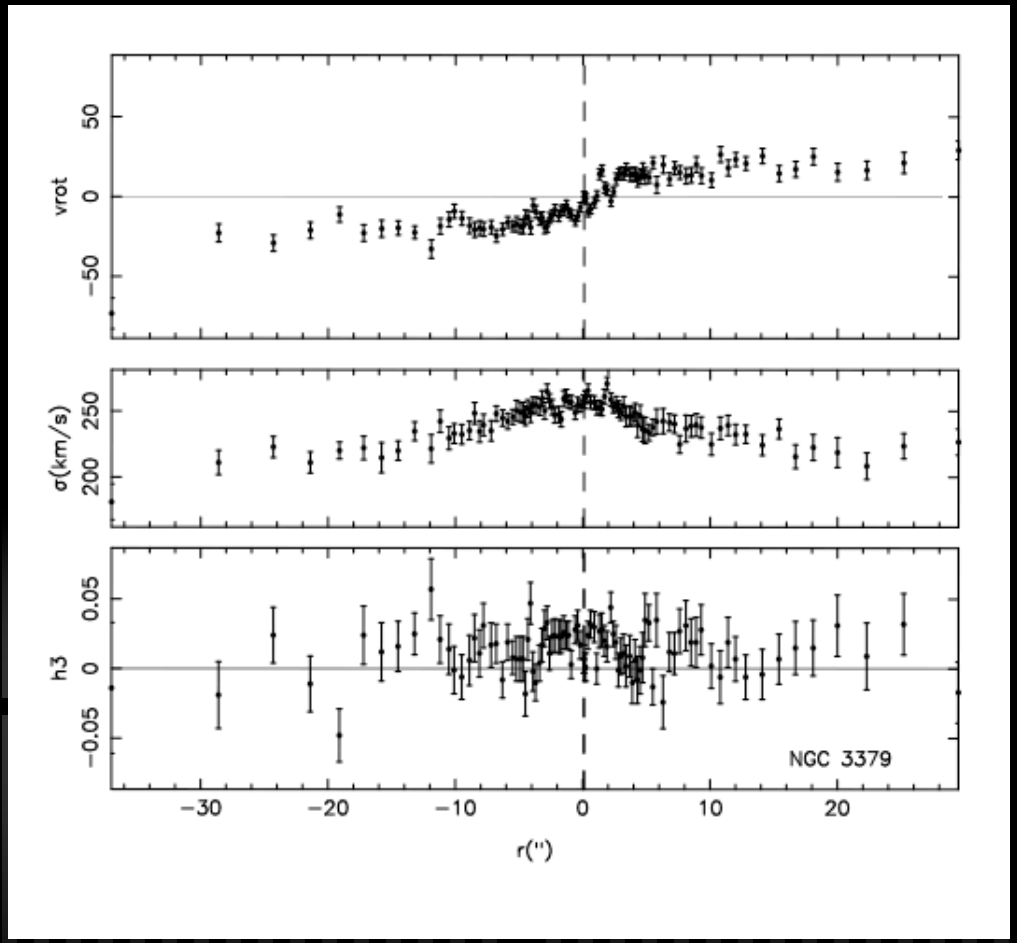


r=0.15”





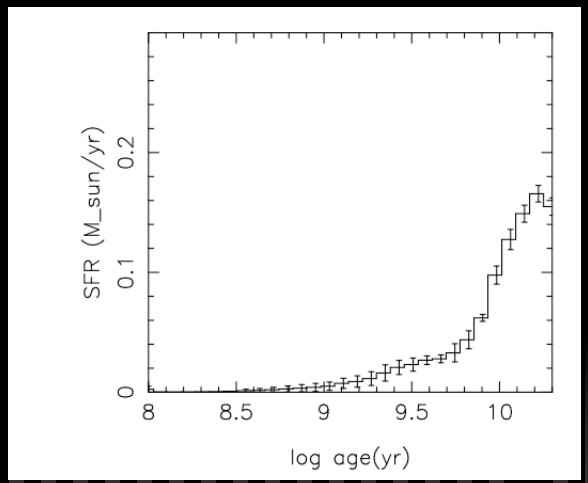




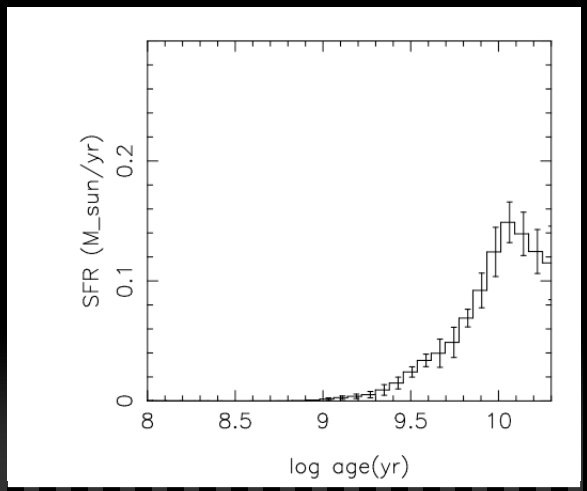
NGC 3379
σ=222.8±1.0
Leo I group
Core
Boxy

Small rotation
Small h3
Central age = 14.2 Gyr

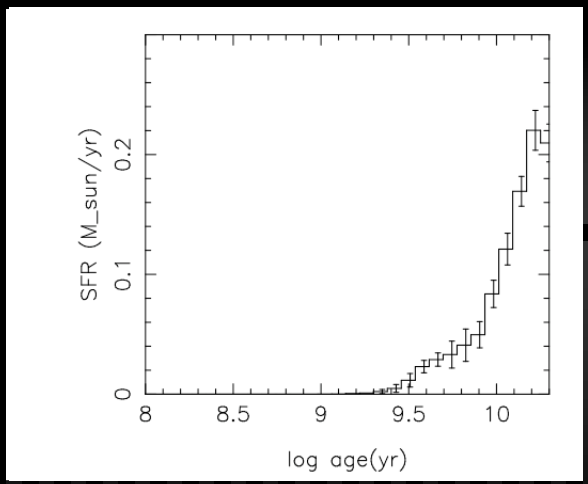
NGC 3379 SFH



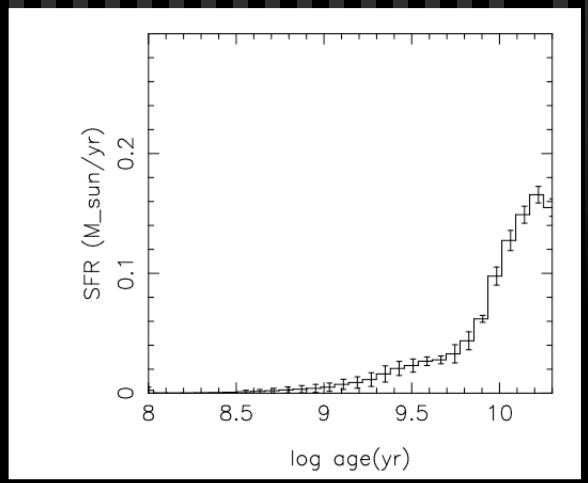
r=37”

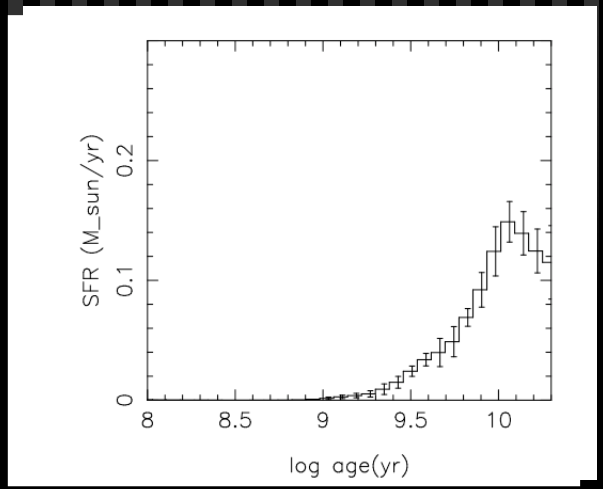


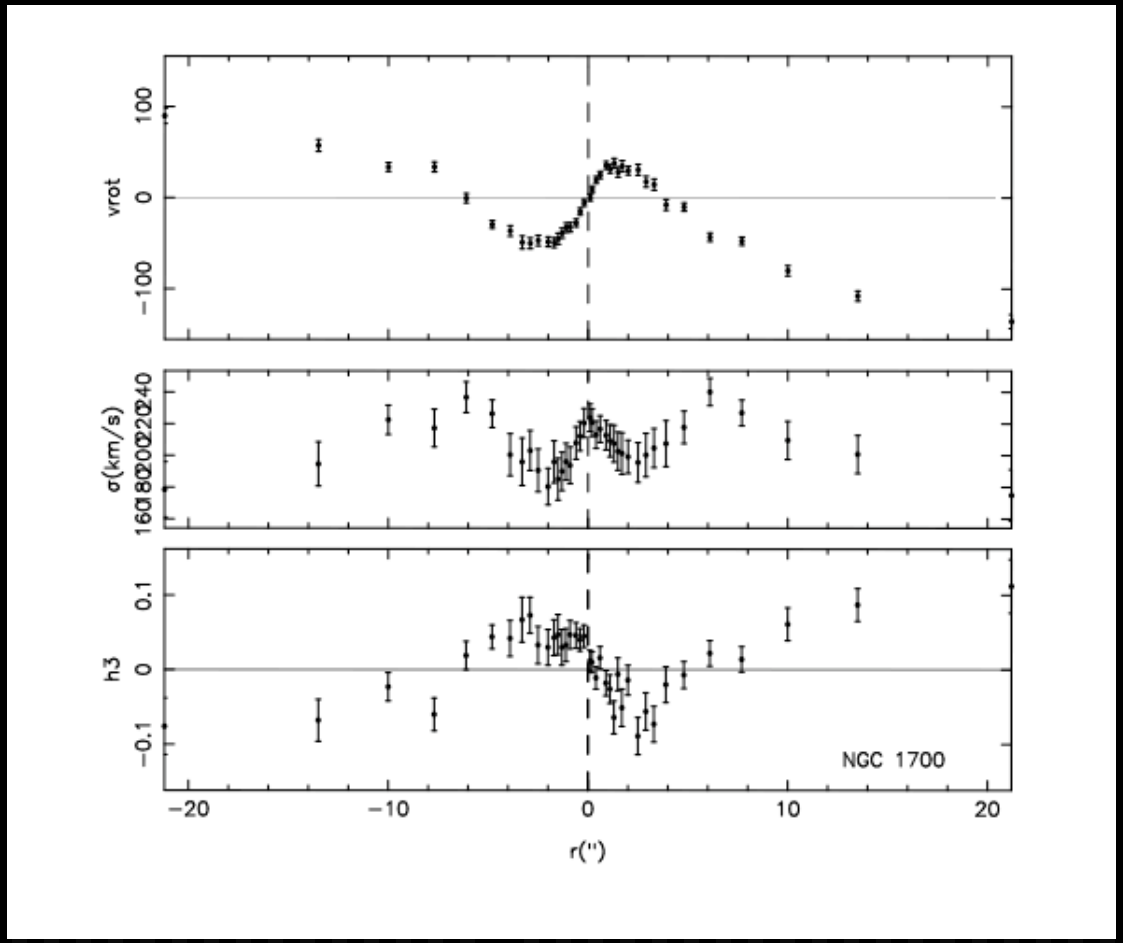
r=11.9”



r=0.2”







NGC 1700

σ=177.7±1.0 kms^{-1}

disky

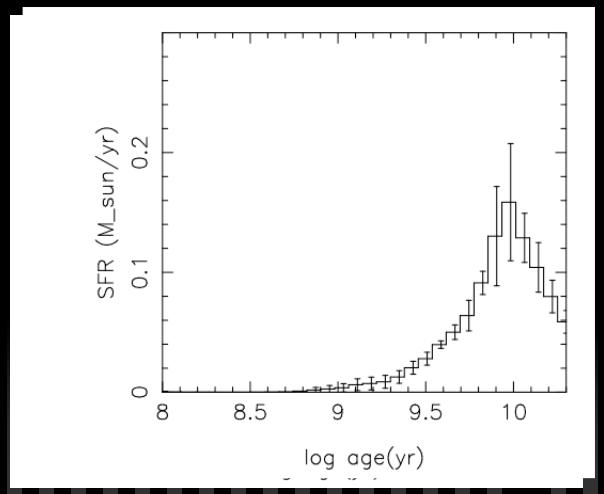
power

Strong anticorrelation between h3 and v

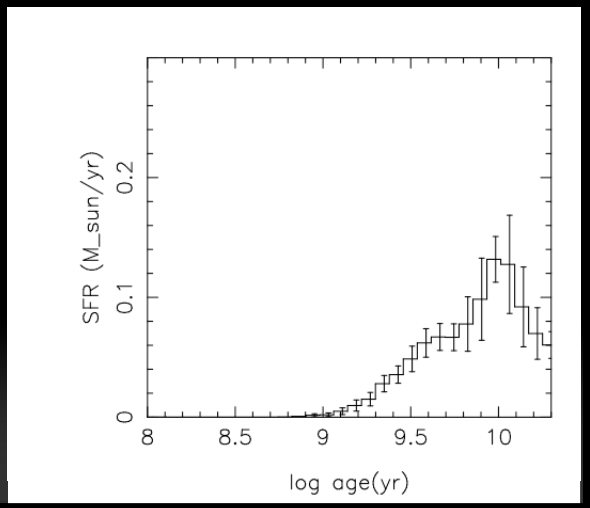
Central age: 2.9± 0.1 Gyr

Counter-rotating core

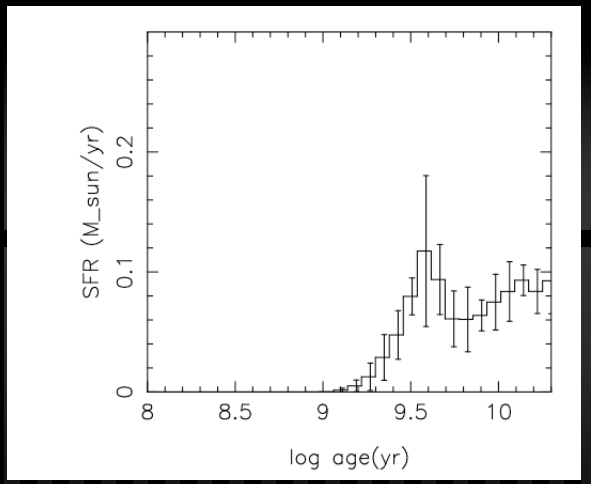
NGC 1700 SFH



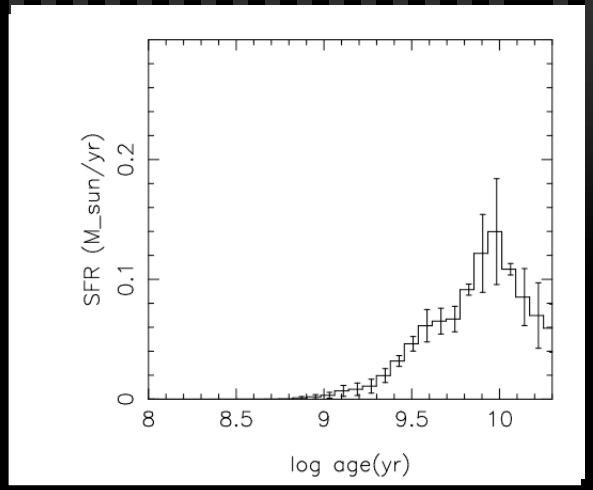
r=21.2”

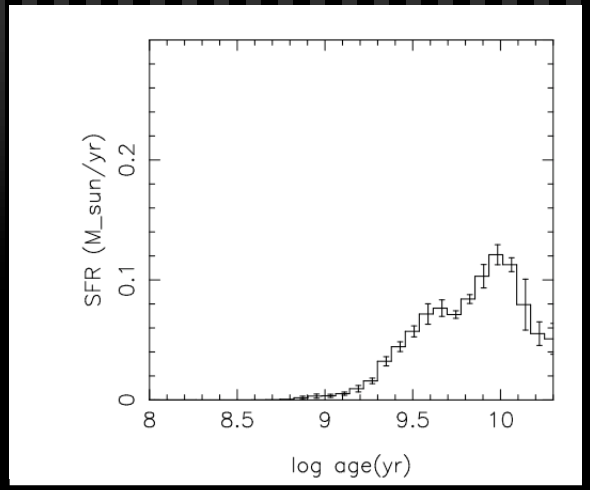


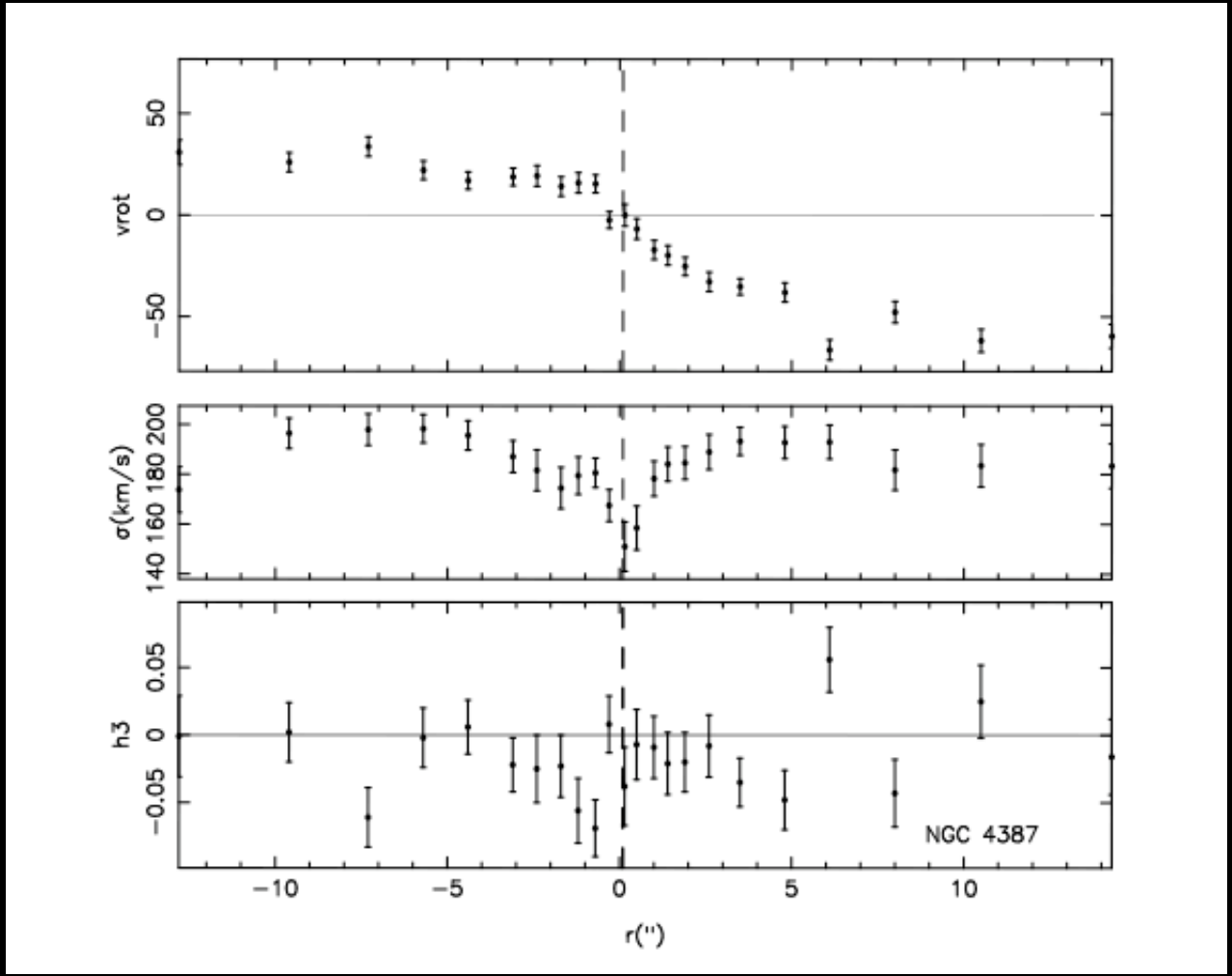
r=2.5”



r=0.2”







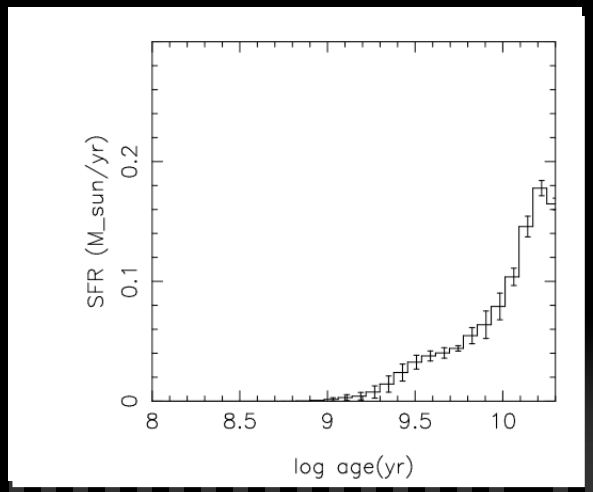
NGC 4387

σ=140.5±1.2 kms^{-1}

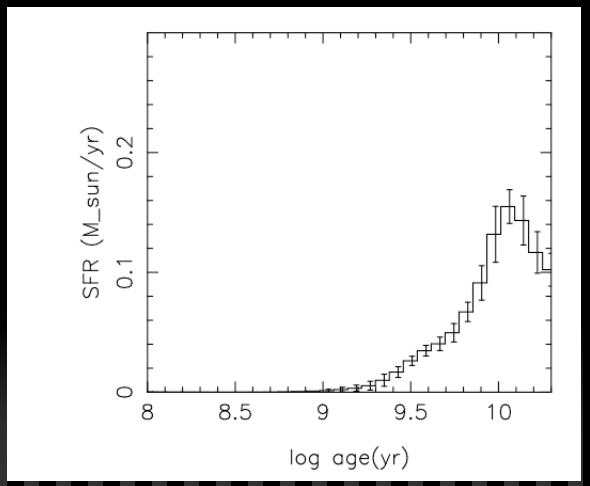
maybe have
a central disk

Central age: 8.8 ± 0.1 Gyr

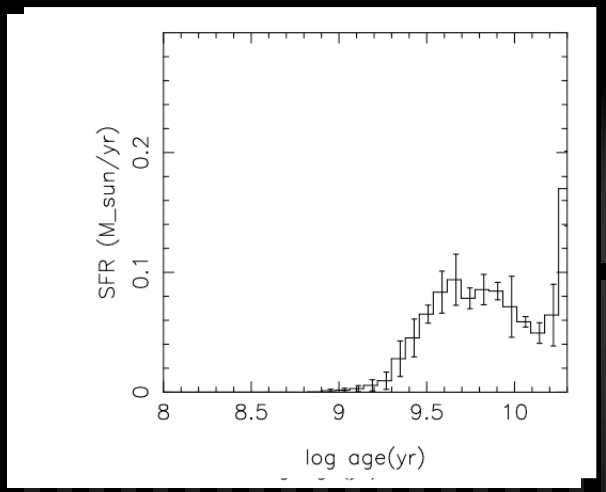
NGC 4387 SFH



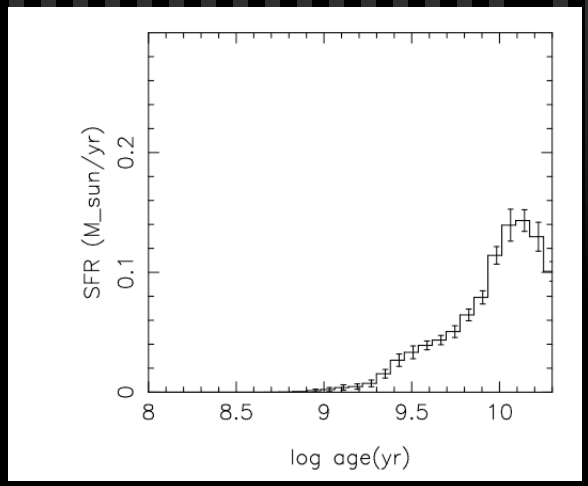
r=12.8”

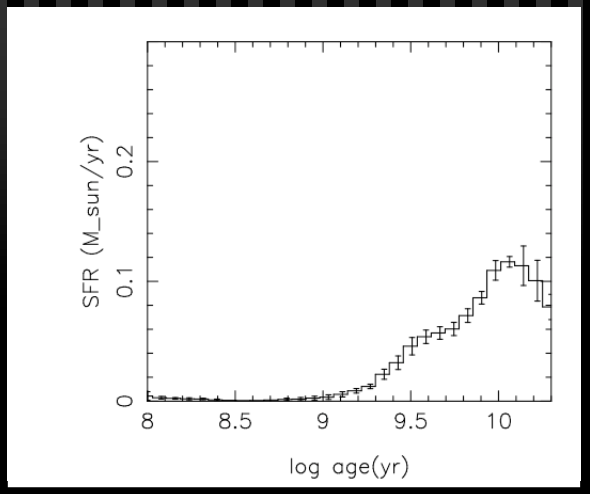


r=2.4”

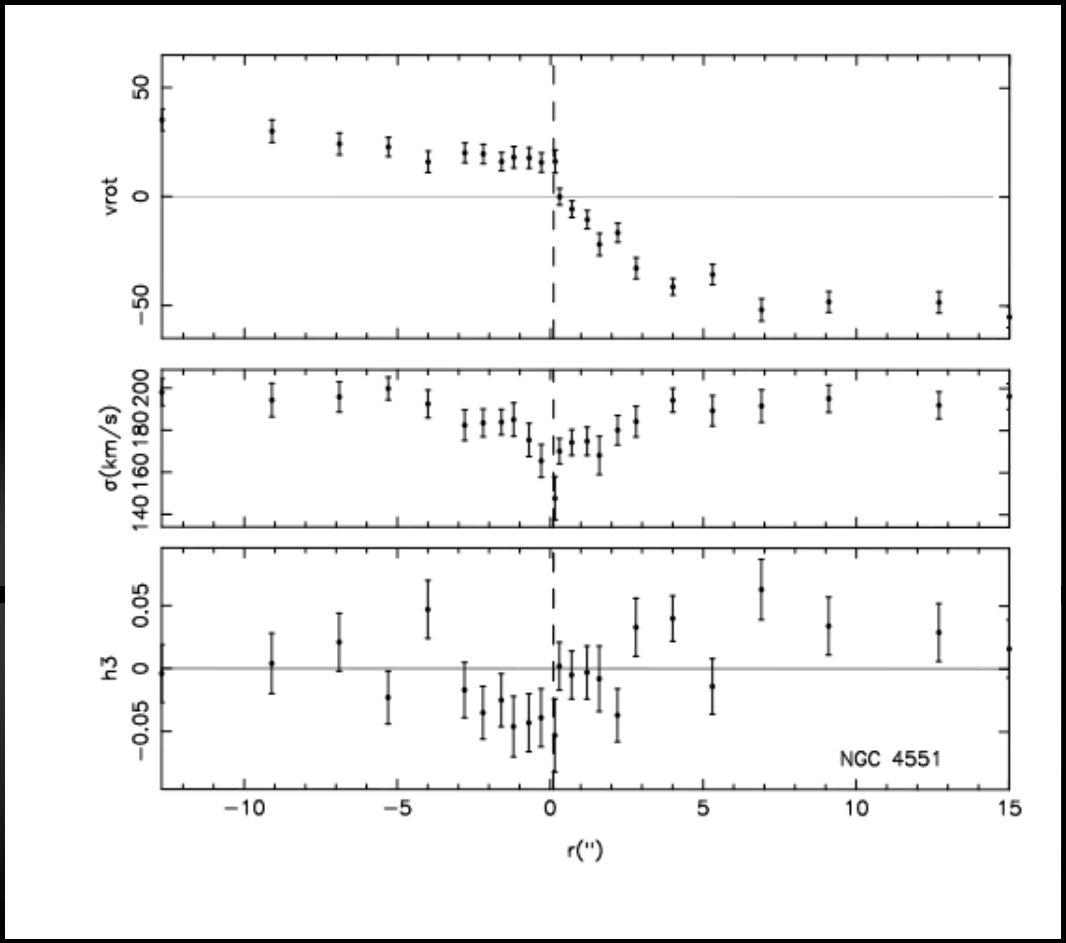


r=0.15”





NGC 4551



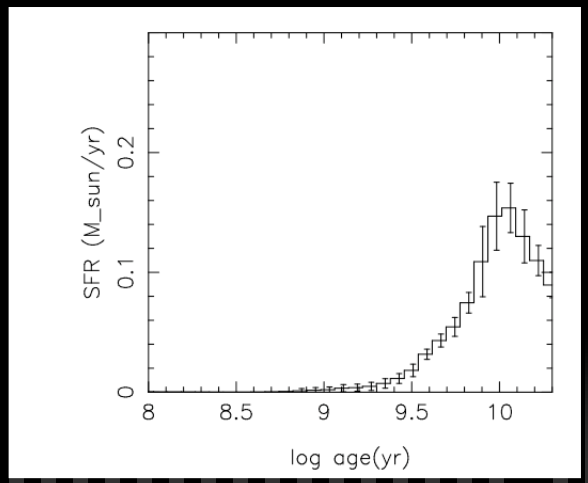
σ= 133.4 ± 7 km/s

Power law

boxy

Central age = 6.5 ± 0.1 Gyr

SFH NGC 4551



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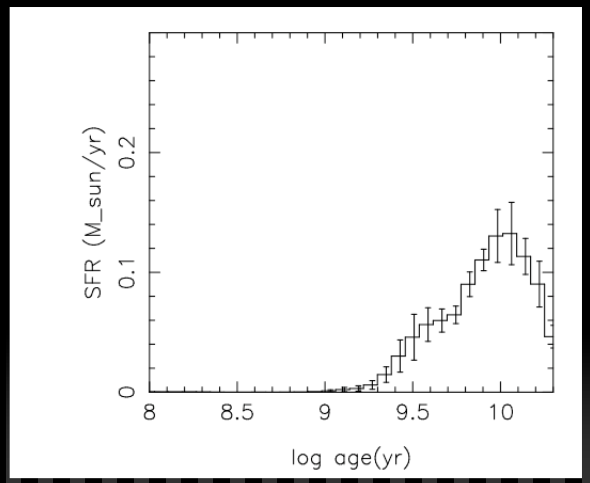
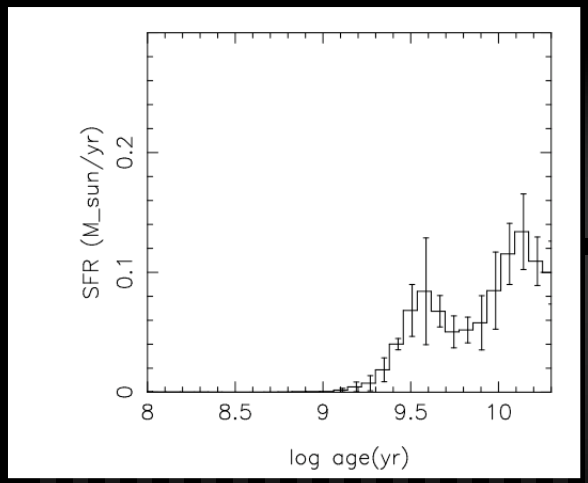
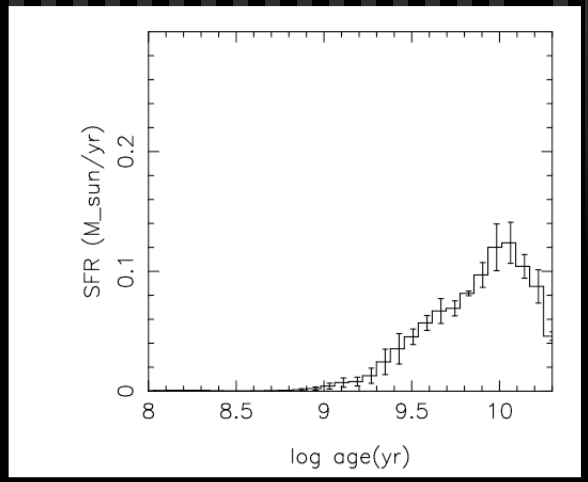
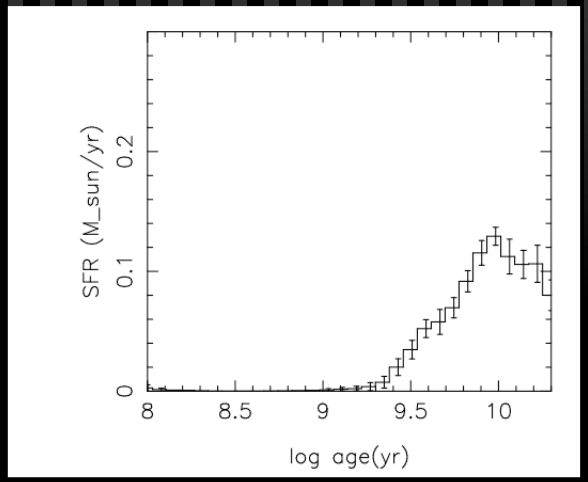


r=9.1”



r=0.1”





General Conclusions

(1) The relation of the gradients with mass, a4, Vmax and the shape of the LOSVD seems to indicate that elliptical galaxies formed through mergers with a systematic decrease, with mass, of the degree of dissipation during these interactions.

(2) The relation between the stellar population parameters in the center and along the radius suggests that the relative recent episodes of star formation that have been observed in the center of a large fraction of E galaxies (Gonzalez 1993; Caldwell et al. 2003, Trager et al. 2000, Sanchez-Blazquez et al. 2006) have been triggered by mergers.

(3) Galaxies with an inner core- or power-law profile seem to show a dichotomy in some relations.

(5) More data of high quality needed!!