Stellar population studies in early-type galaxies using PNe

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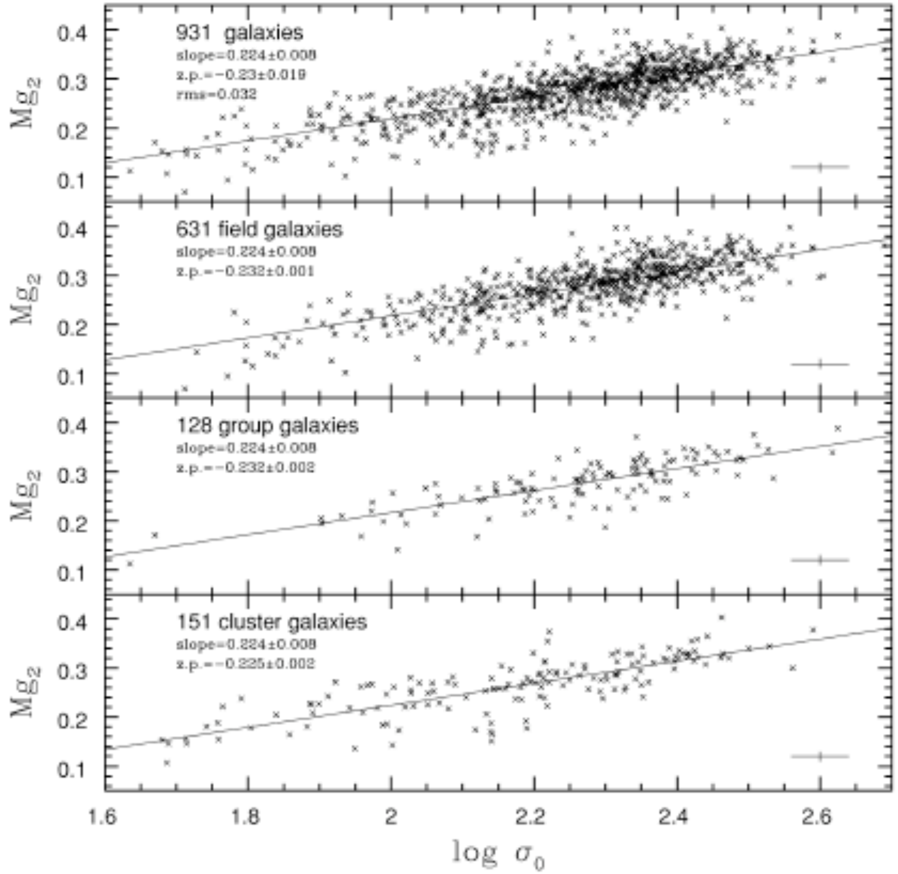
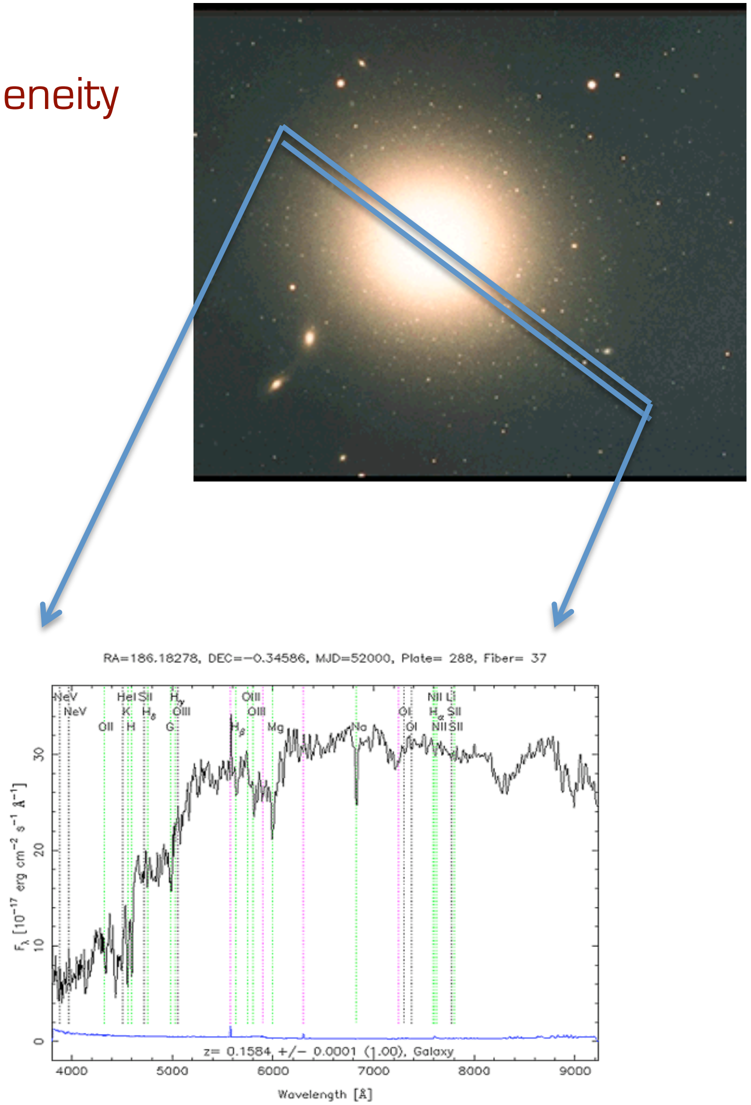
Motivation: How do early-type galaxies form?

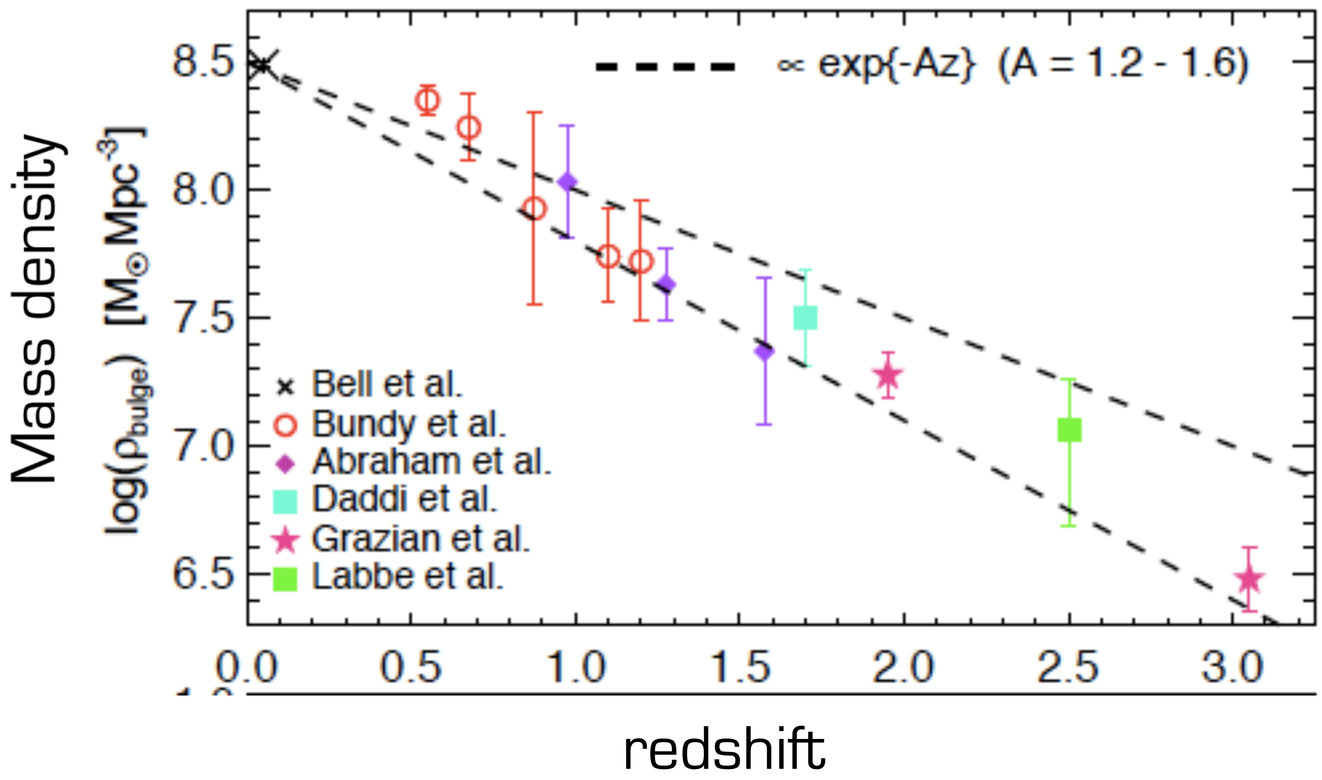
Central properties: ET galaxies show strong homogeneity



Bernardi et al. 1998

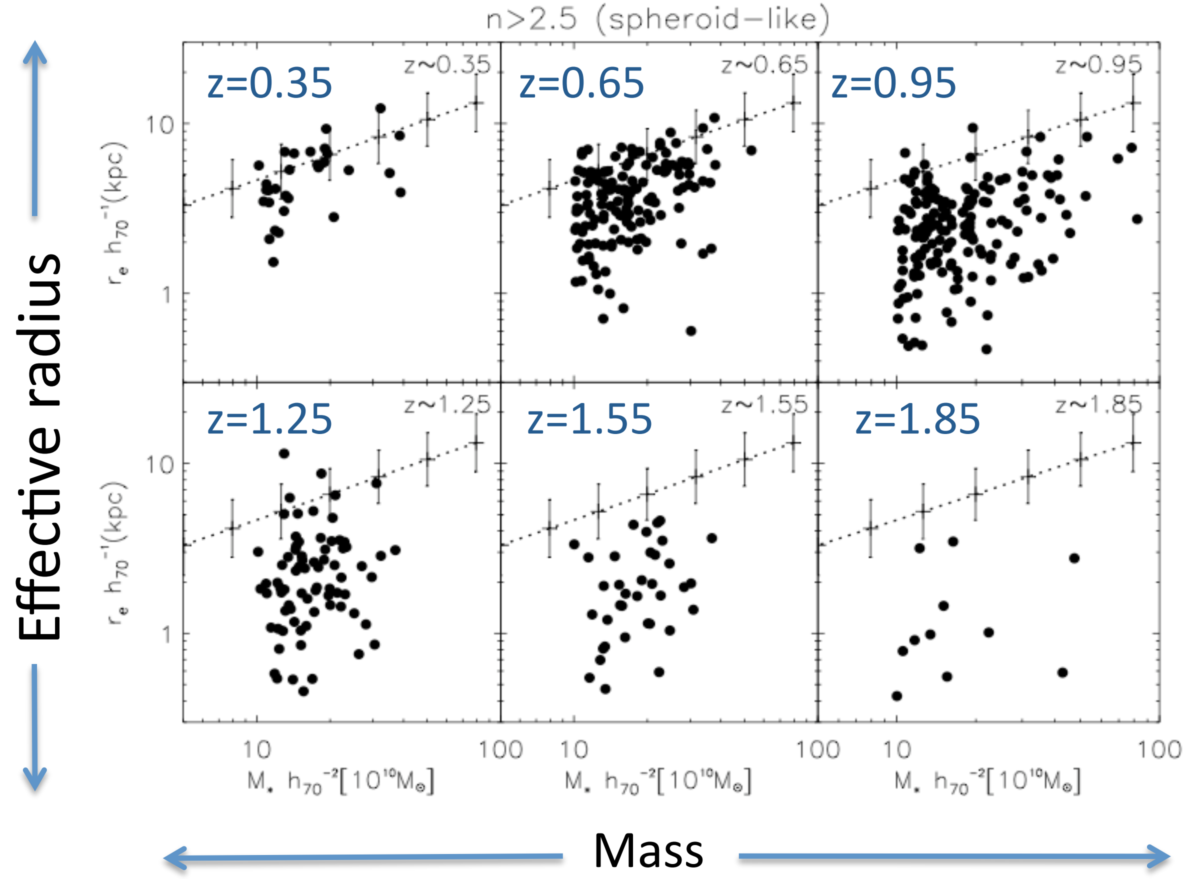


Motivation: How do early-type galaxies form?



At z=2 only 5% of the stellar mass in elliptical galaxies at z=0 was already in place.

Motivation: How do early-type galaxies form?



Proposed scenarios:

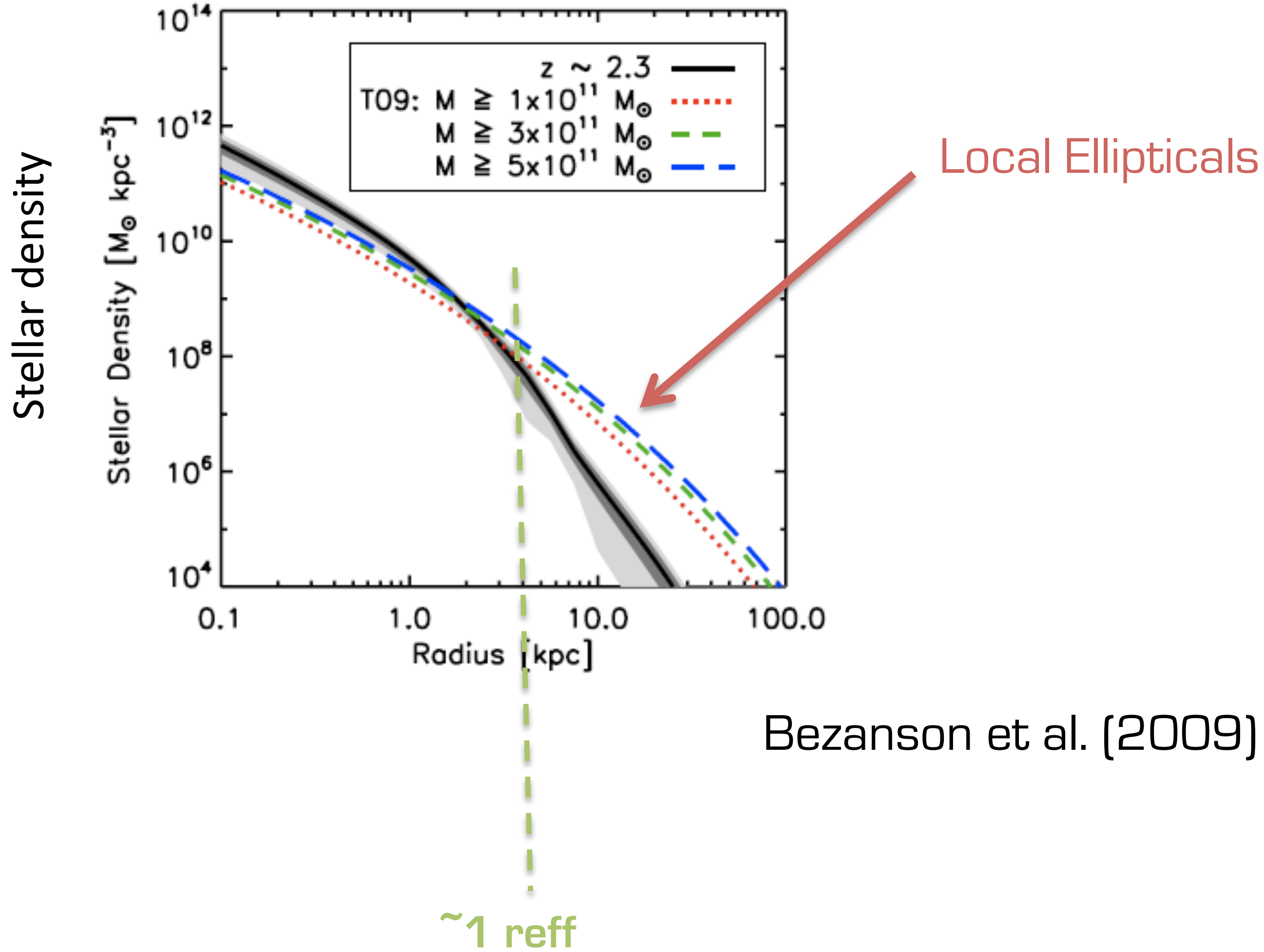
Major Dry mergers?

Accretion of satellites?

Adiabatic expansion?

Massive, quiescent galaxies have increase their size by about a **factor of 5 since z ≈ 2** (Trujillo et al. 2006; Longhetti et al. 2007; van Dokkum et al. 2009; Cimatti et al. 2008; Franx et al. 2008)

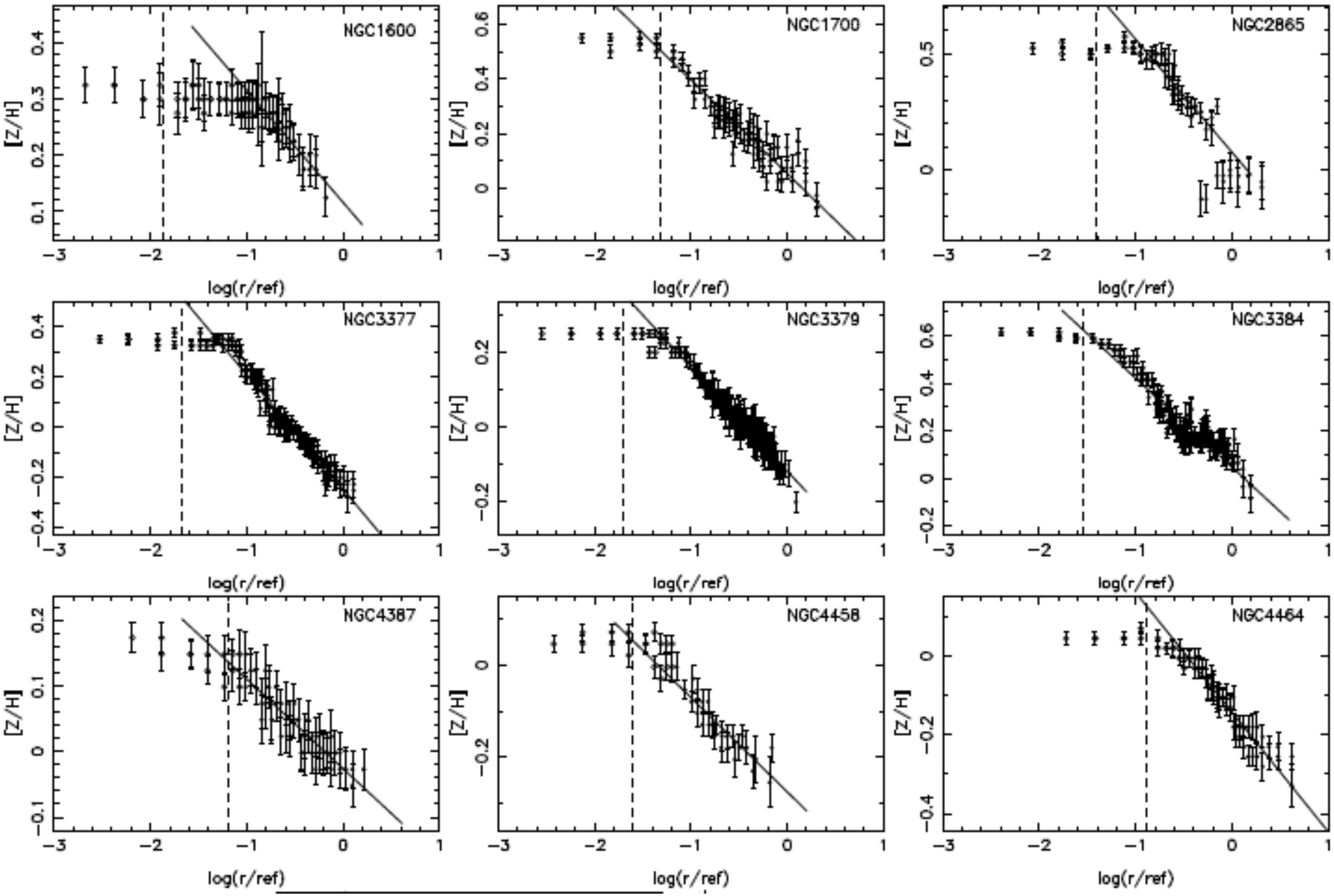
How do early-type galaxies form?



Bezanson et al. (2009)

Metallicity gradients in early-type galaxies with integrated spectra

PSB et al. 2007



Main problems with deriving SFH with integrated stellar spectra

- Age-metallicity degeneracy
- Non-solar abundances (different metallicities using different indicators)
- Presence of hot population (BHB, blue straggles)

PNe

All populations older than $\approx 10^8$ yr make PN and in a large galaxy, hundreds are available for study.

We can observe them up to very large radius.

If one can measure [OIII]4363, [SII]6716,6731 and [NII]6548,6584, then one can directly measure a population's abundance distribution function and constrain its history of chemical enrichment.

Possibility of getting, not only the mean values but also the dispersion

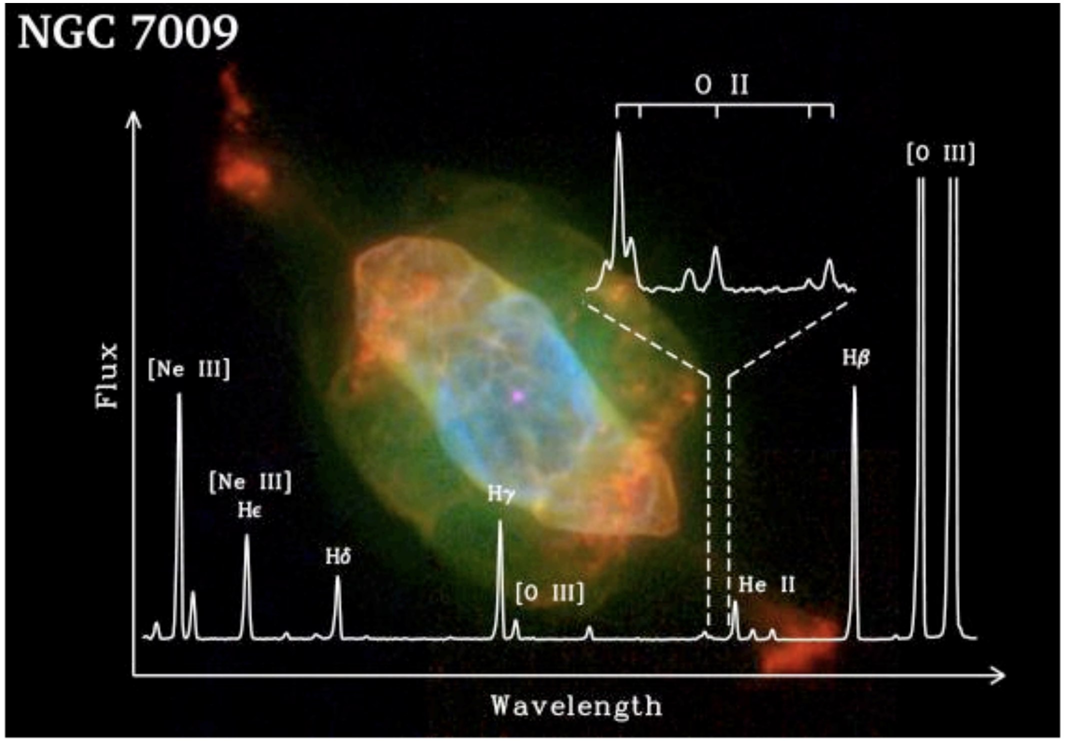
Measuring Metallicities in PNe

- (1) Obtain the Te from the [OIII]4363/5007 or [NII]5755/6584 ratios
- (2) Obtain electron density [SII]6716/6730
- (3) Obtain O+/H ratios from [OII]3727/Hbeta (or [OII]7325/Hbeta) and compute the ionic abundances.
- (4) apply the ionization correction factors

The abundances of Ne, S, Ar, Cl and (in some cases) O can be considered as representative of the IM at the time of formation of these stars.

Facing reality: Obtaining metallicities with PN is hard

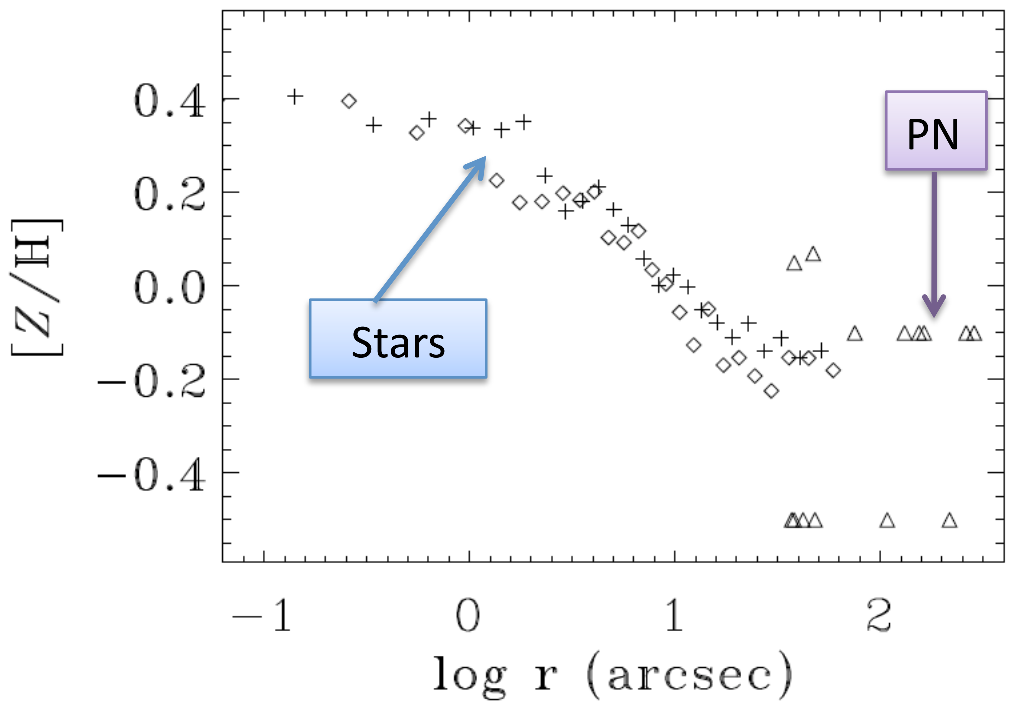
- [OII]4363 is 1/100 of [OIII]5007 for Te≈12000K
- If we can get Teff-> we can get Ne,S, Ar and O (unprocessed α-elements) → age of the PN.



Previous attempts with 8m-class telescopes

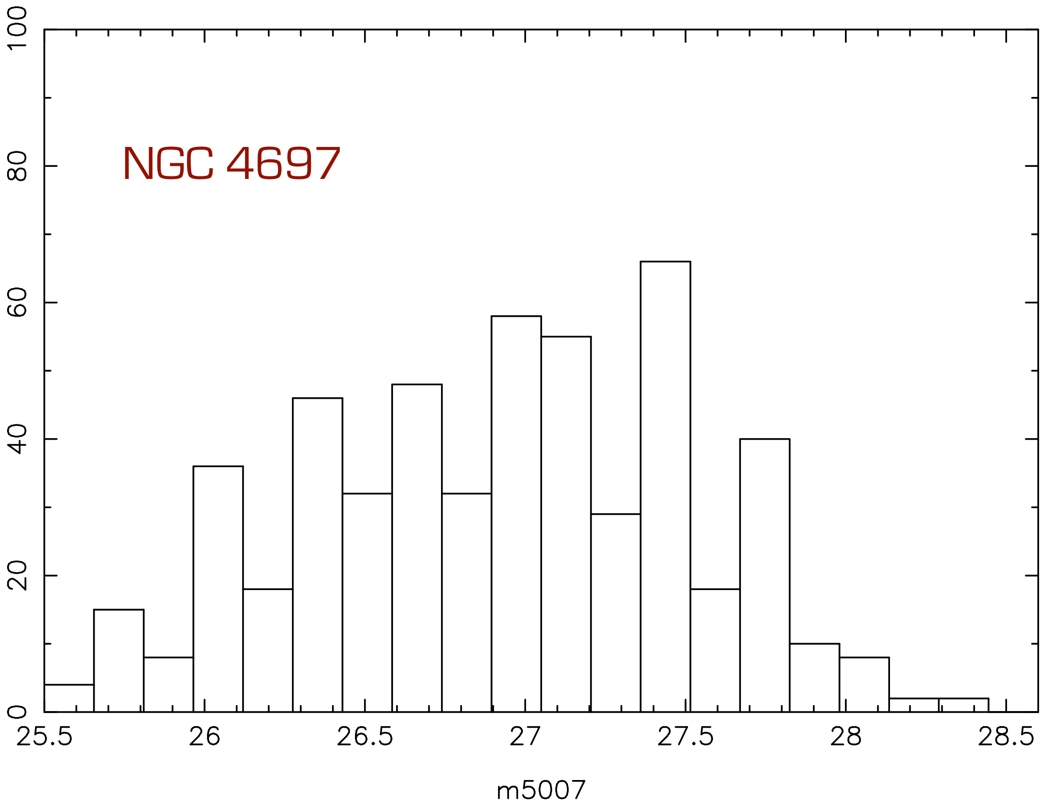
- Mendez et al. (2005) (20h using FORS1 at the VLT); Walsh et al. (1999) (only lower limits)

NGC 4697
d=11 Mpc



42 PNe in M31 bulge (Richer+1999; Jacoby & Ciardullo 1999), Also in M32 (Stasinka et al. 1998; Richer et al. 2008) and NGC5128 (Walsh et al 1999)

What can be done with the ELT?



What can be done with the ELT?

- Spectral resolution: 1000-5000
- Wavelength coverage ~3000-11000
- Typical magnitude: 27
- Flux=1-1.5x10^{-19} erg cm^{-2} s^{-1} A (for [OIII]4363)
- Typical exposures times =20h
- With a 30m: out to ~7 Mpc
- With a 42 m: out to ~15 Mpc

Three regimes

- Weak line spectroscopic regime (when one has knowledge of faint forbidden lines, as [OIII] λ4363.
- Bright line regime: where only the strongest emission lines ([OIII]λ5007, [NeIII] λ3869, Hα and Hβ) are visible.
- Photometric regime: where the only information available is the [OIII] λ5007 luminosity function.

Regime 2

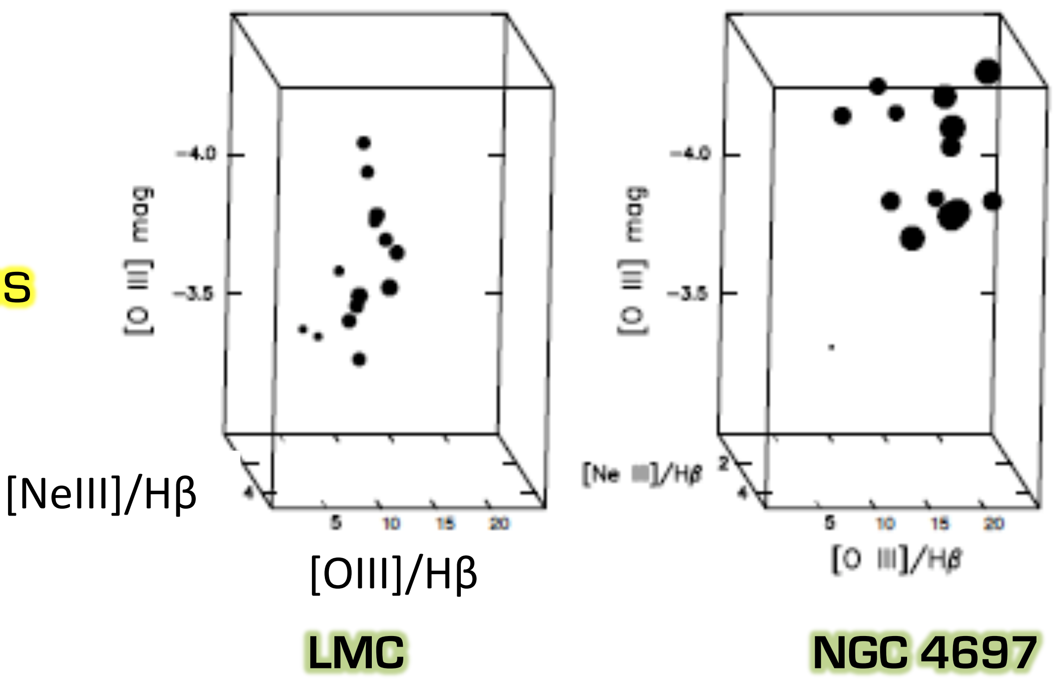
If [OIII]4363 cannot be detected

[OIII] λ 5007, [NeIII] λ 3869, Hα,Hβ

-Constrains on the maximum metallicity using [OIII]λ5007/Hβ

-Characterise different types of PN depending on the environment (metallicity, relative abundances, etc)

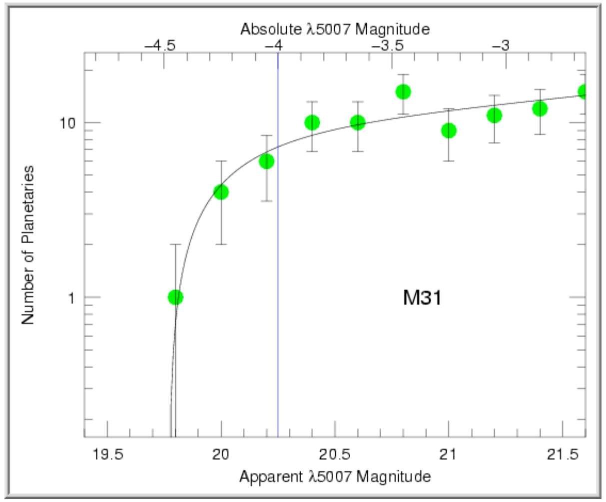
Calibrate these ratios as a function of SP parameters



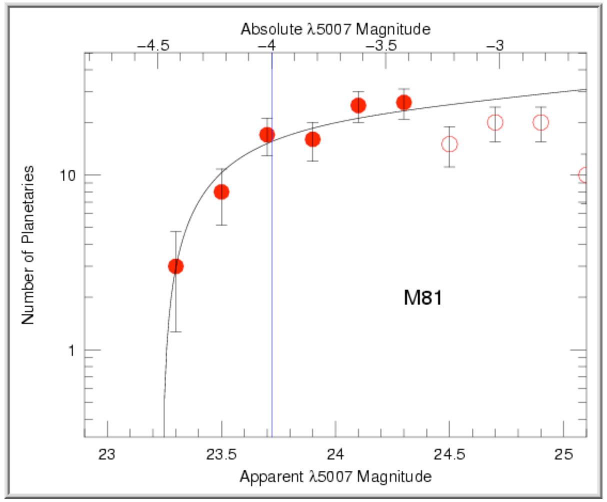
Ciardullo et al. 2002

Regime 3

PN luminosity function



The Magnitude of the bright cut-off is Universal M*=-4.5. In all types of galaxies and in different parts of the same galaxy



PNLF obtained for ~20 early-type galaxies up to distances of ~10 Mpc.

$$N(M) \propto e^{0.307\,M}\{1 - e^{3(M^* - M)}\}$$

Where M=-2.5 log F_{5007}-13.74

PNLF

But why doesn't the PNLF depend on age? According to stellar evolution …

- Younger populations have higher turn-off masses
- Higher turnoff masses produce higher mass central stars
- Higher mass central stars have higher Post-AGB luminosities
- Brighter central stars mean greater [O III] λ5007 fluxes

Difficulty to explain the observed invariance of the cut-off in galaxies from late to early types:

The absolute luminosity of the cutoff demands that the central star > 0.6 Msun (progenitors with main-sequence masses close to 2.2 Msun):

For ellipticals:

a) Recent burst of SF in ellipticals?

b) Something missing in the models? (yes, but e.g. extinction makes PNe fainter, not brighter)

c) Could larger MCSPN or higher [O/H] at low Z produce such bright PNe at old ages?

d) Some exotic type of PNe in ellipticals?

e) other mechanisms create high-core mass PN (blue straggles (Ciardullo et al. 2005), BHB?).

Some numbers

d(Coma)= 93 Mpc (Ho=75 km/s/Mpc)

M*(5007)=-4.5 → m*(5007)=30.34 → F*(5007)=2.34 x 10^{-18} erg/cm^2/s

	S/N (GTC (10.4m))	S/N (ELT)
m*+2.5 (Coma)	S/N=4→ 36 hours→ 4 nights 30 fields→ 120 nights x 3	30 fields→ 8 fields Total= 25 nights
7 arcmin size	12 fields→ 144 nights	12 fields→ 10 nights

Conclusions

- PNe to obtain SFH and constrains in SP studies are largely unexploited: although a lot of work remain to be done, they have the potential to revolutionize our studies of stellar populations in early-type galaxies

- Different studies can be applied to galaxies at different distances. Some of them are not viable with the current generation of telescopes.