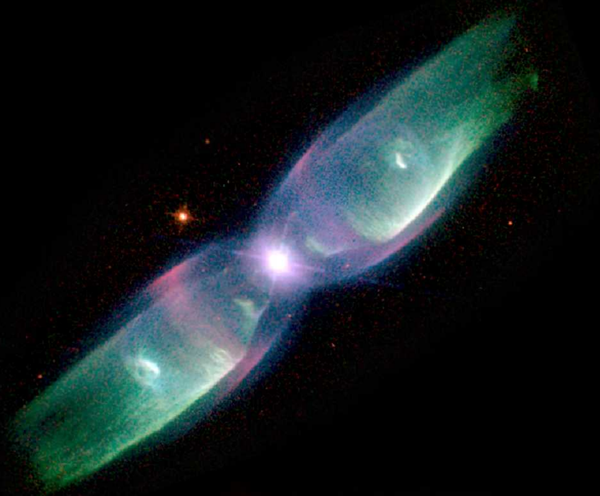
Maintaining dead galaxies with stellar heating



Charlie Conroy
Pieter van Dokkum

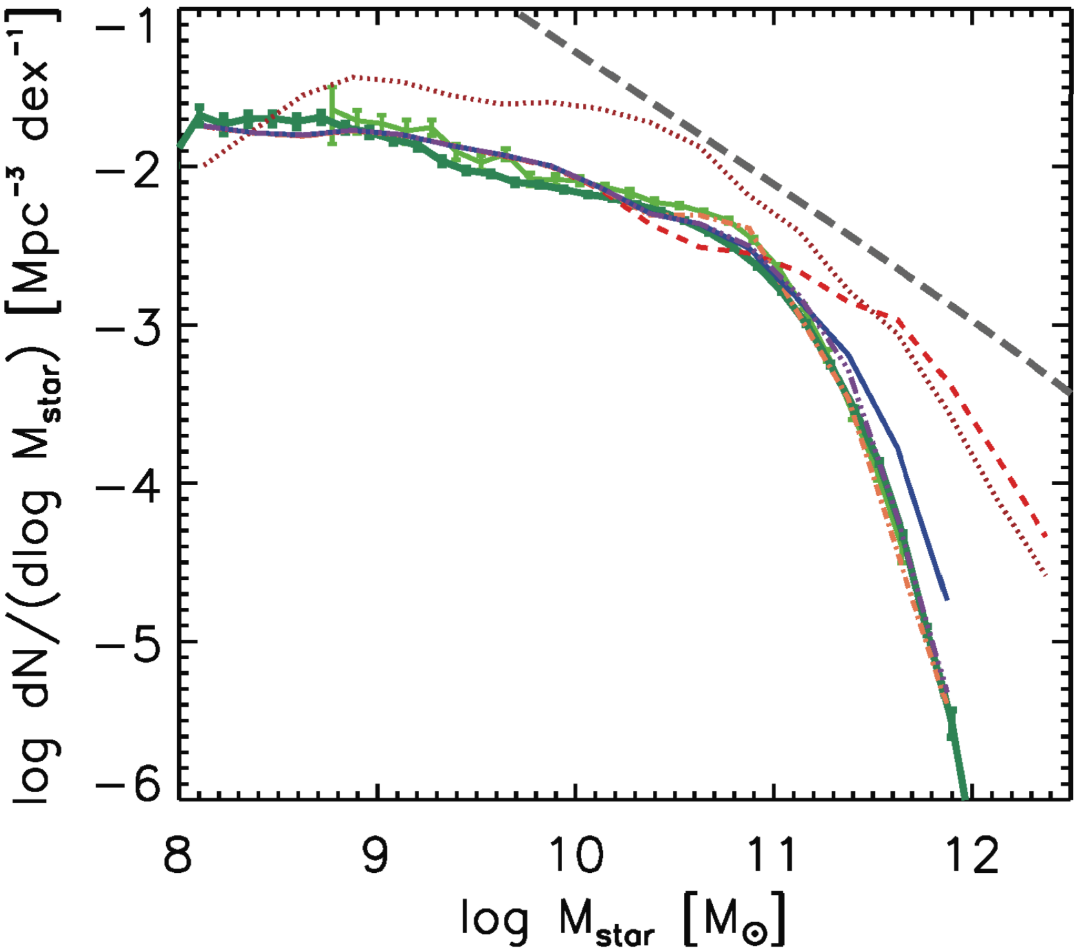
Why do these galaxies exist?

The Standard Lore: “AGN Feedback”

- **Quasar Mode**
  Merger-driven. Drive out/ exhaust gas supply

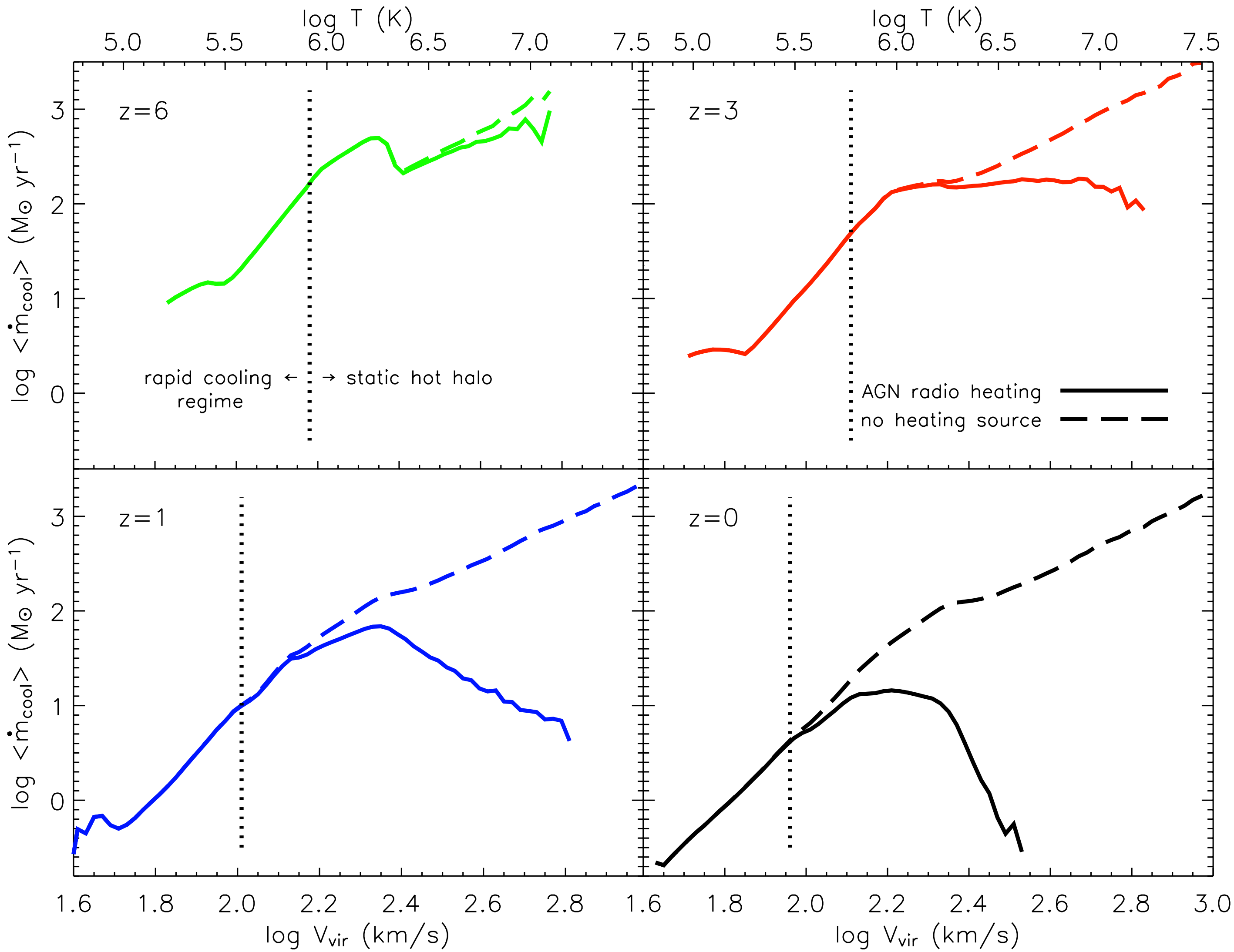
- **Radio Mode**
  Energy from BH maintains a hot atmosphere
  Related to the “cooling flow problem” in clusters

Binney & Tabor 1995
Ruszkowski & Begelman 2002
Springel et al. 2005
Croton et al. 2006
Hopkins et al. 2008
etc. etc.



Somerville et al. 2008

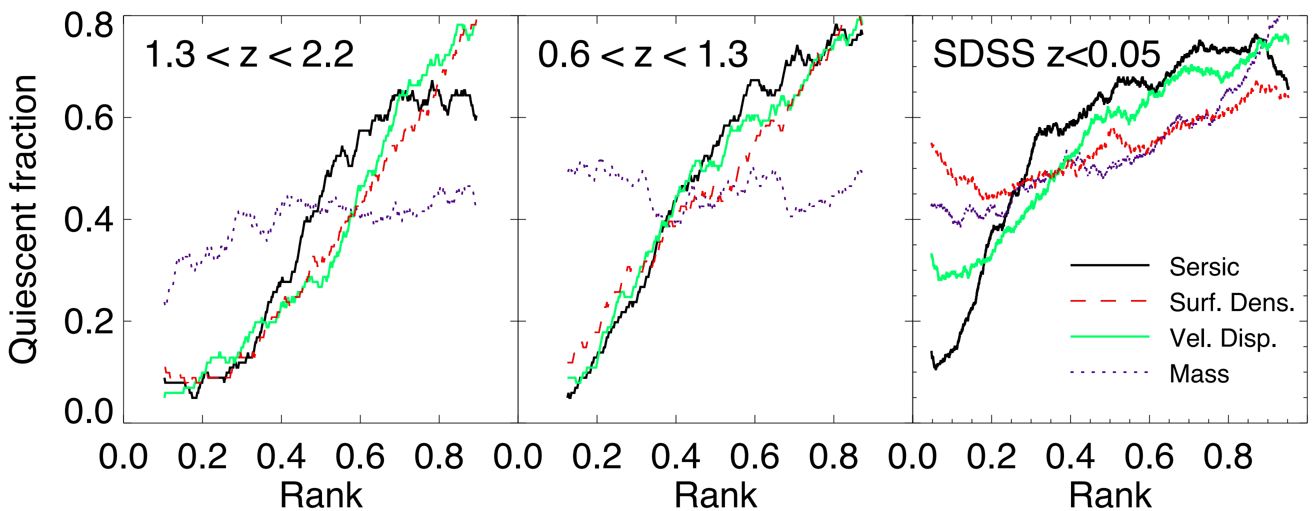
Radio Mode Feedback = "Maintenance Mode"



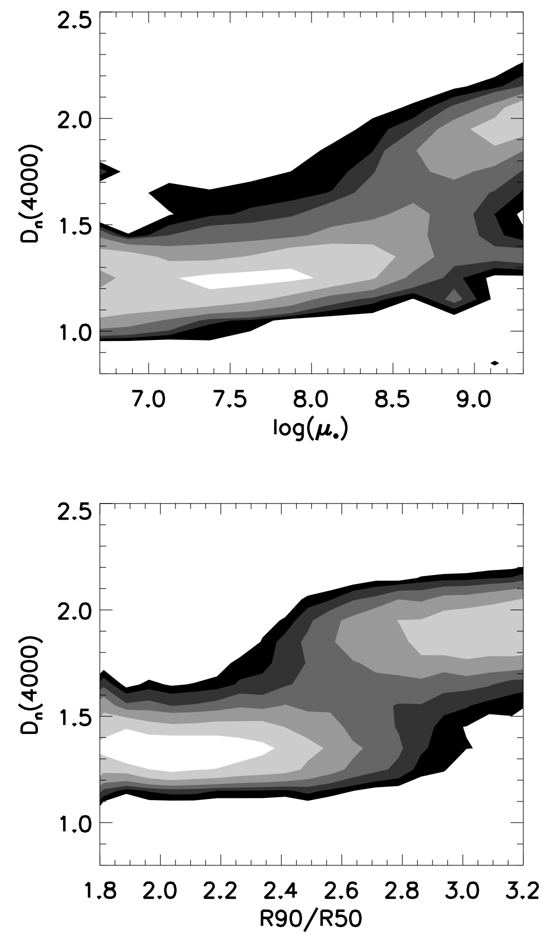
Croton et al. 2006

Recent Clues

- SF quenching strongly correlated with galaxy structure (stellar density)
- Lots of massive quiescent galaxies at z>2

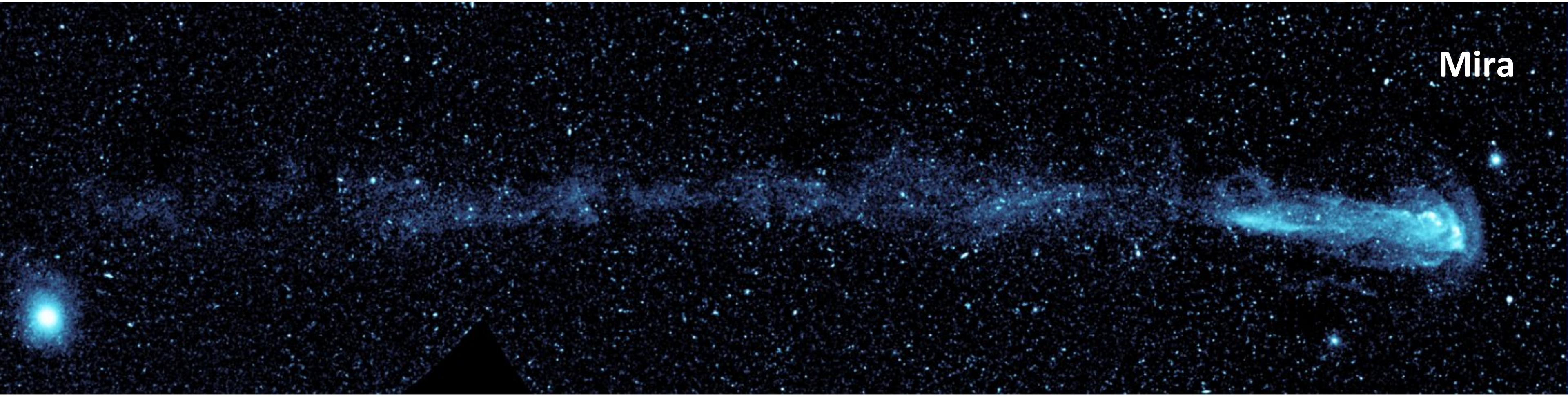


Bell et al. 2012

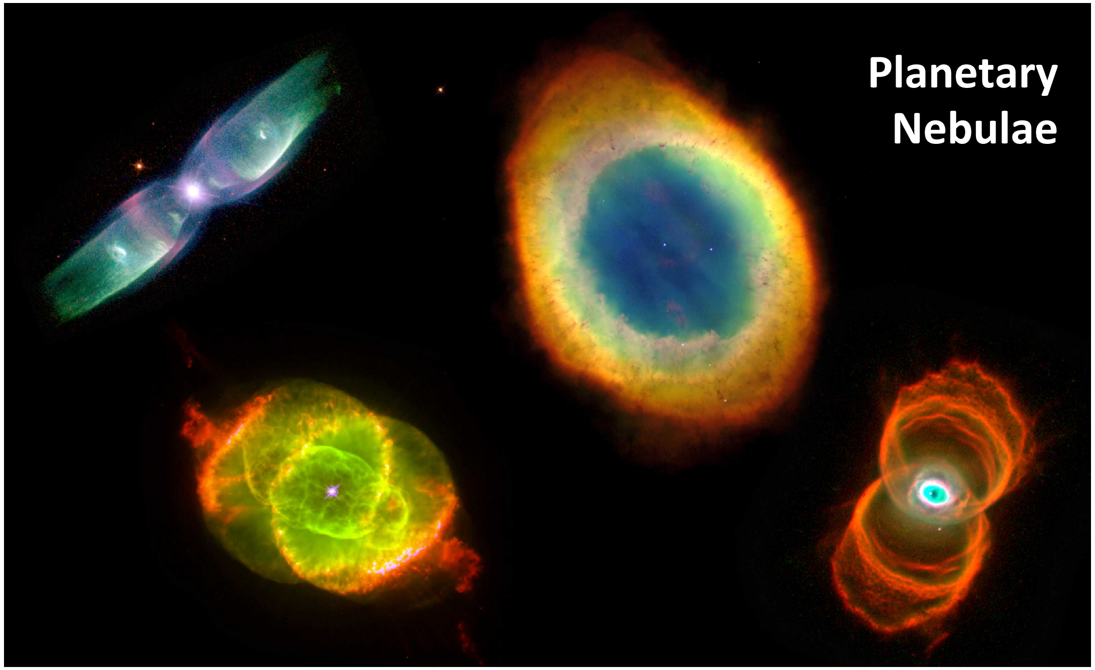


Kauffmann et al. 2003

All Stars Die



- Stars less than <~8 M_{sun} die quietly, ejecting their outer envelopes in a super-wind phase
- They evolve to **post-AGB** stars, in many cases passing through a PNe phase



Overview of Post-AGB stars

Post-AGB stars live for ~10^4 yrs at high T_{eff} and high L_{bol}

Expect ~1 pAGB star *at any time*, per 10^7 stars

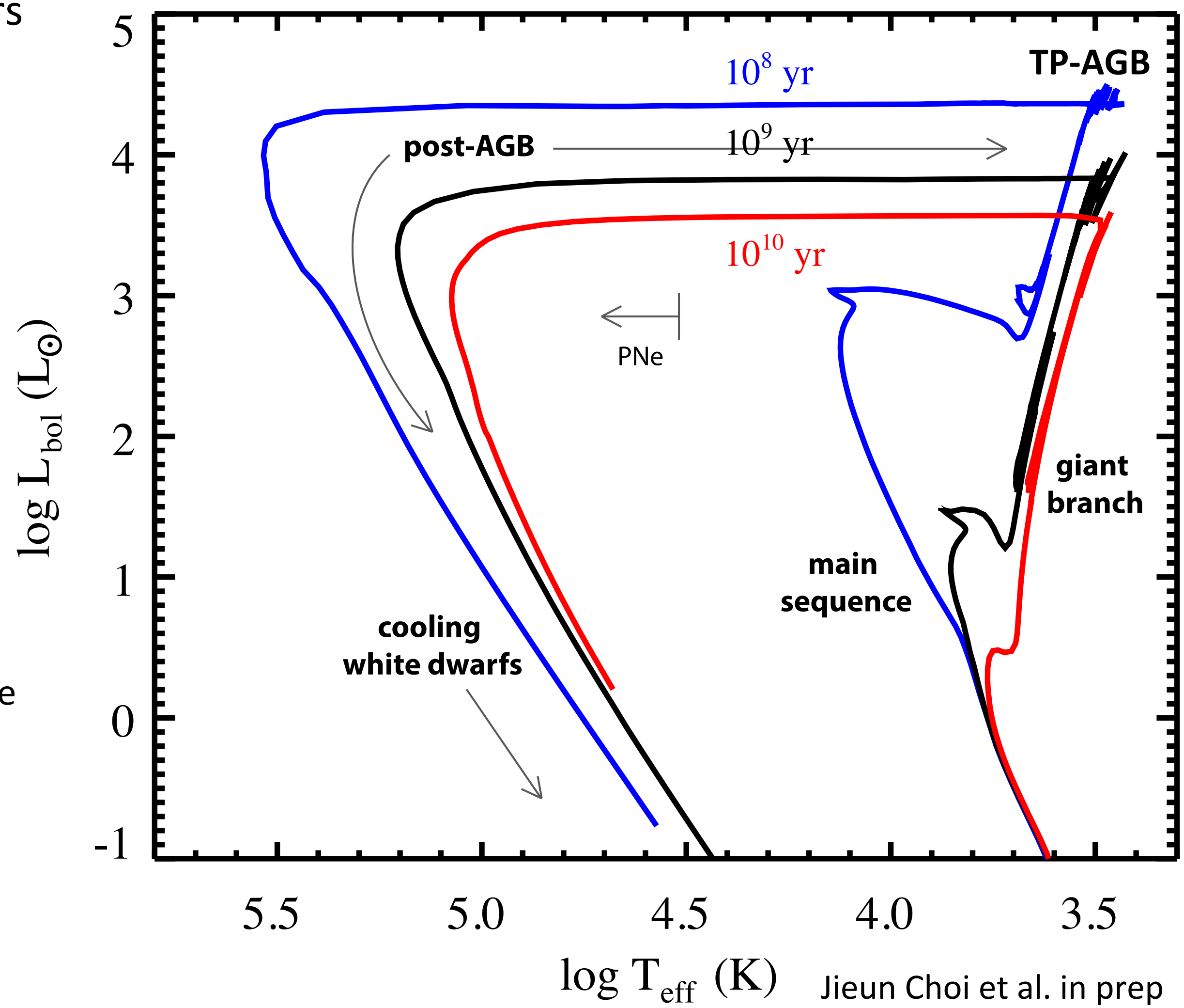
Two sources of energy:

1. mass-loss
   approx instantaneous
   wind velocity ~20-40 km/s
2. ionizing radiation

Main uncertainties:

1. Mass-loss rate prior to envelope ejection (controls core mass)
2. Residual mass-loss rate during post-AGB phase

MIST – MESA Isochrones & Stellar Tracks



Jieun Choi et al. in prep

An Example

Typical quiescent galaxy at z=2:

- $M_{star}=10^{11}\ M_{sun}$, σ=300 km/s, R_e=1.5 kpc; $M_{halo}=10^{13}\ M_{sun}$

Heating Sources (from pAGB stars):

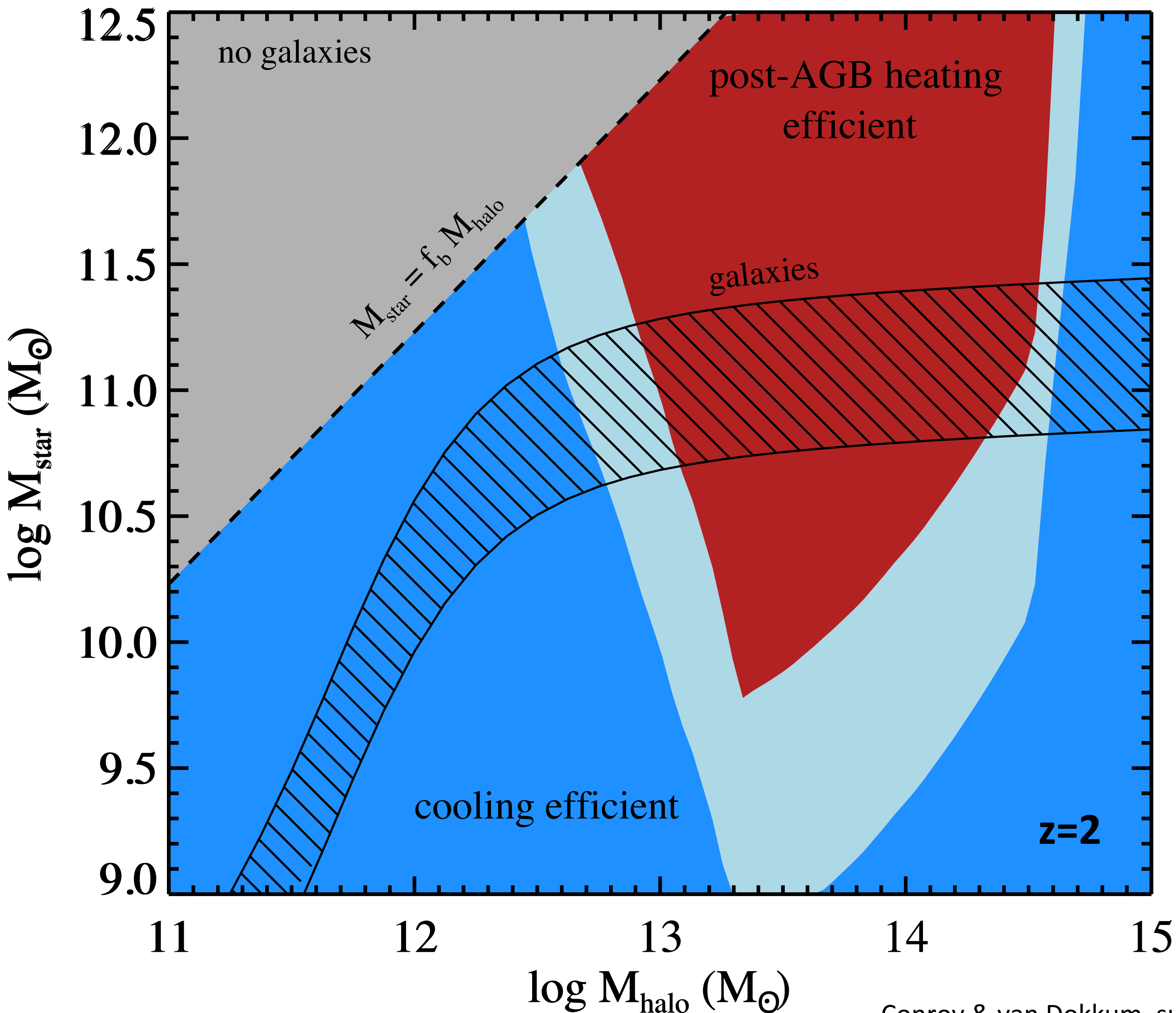
- Ionizing luminosity = $10^{41.7}$ erg/s
  - Taking $L_{bol}=10^4\ L_{sun}$, $T_{eff}=10^5$ K
  - Consistent with detailed SPS models
- Wind heating = 3/2 dM/dt σ^2 = $10^{41.3}$ erg/s
  - dM/dt ~ 1-2 M_{sun}/yr

Cooling Source:

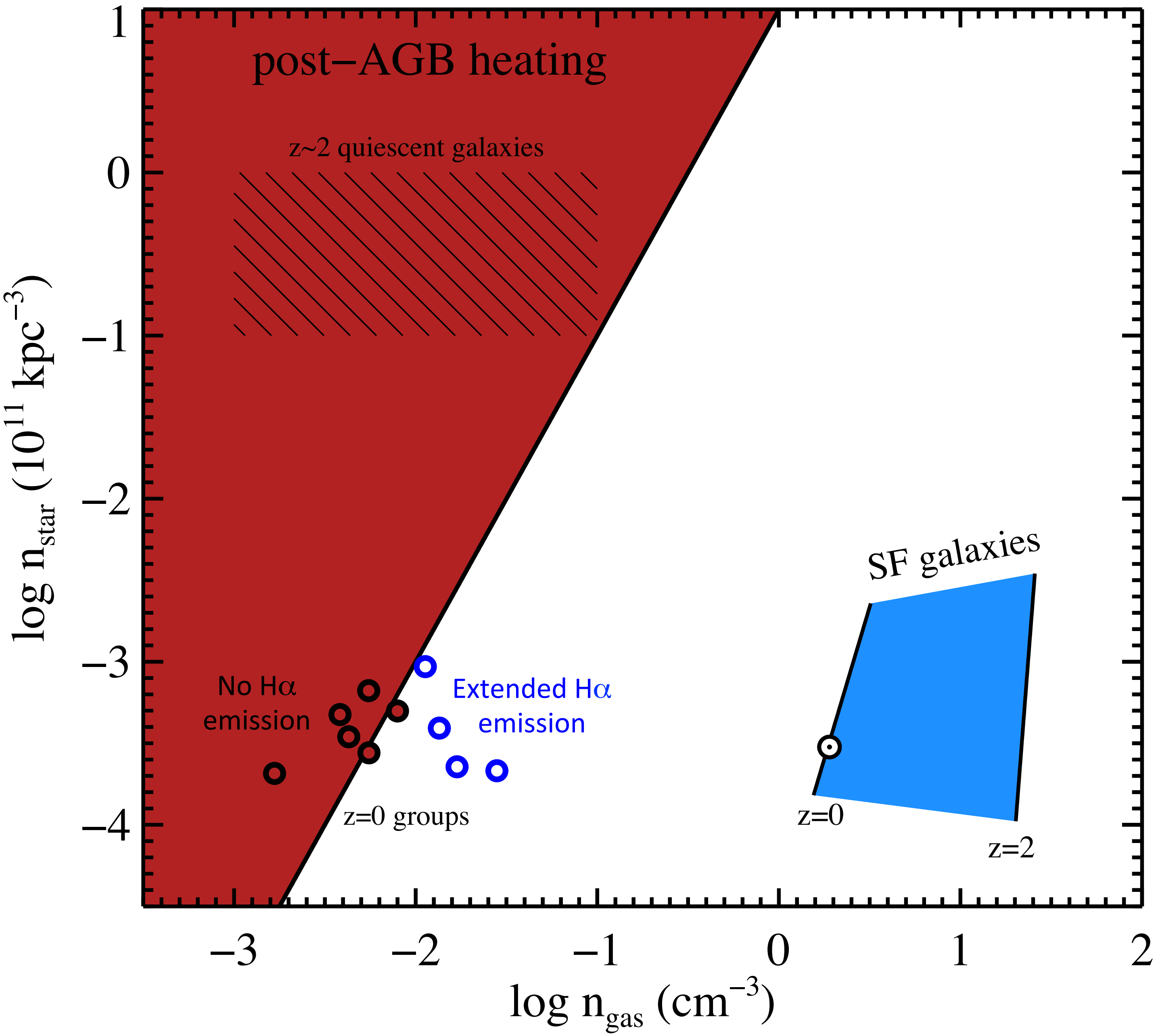
- Radiative Cooling = 10^{41} erg/s
  - Assuming 10% gas fraction, in hydro equil with NFW halo, $T_{vir}=10^{6.8}$ K
  - Computed within the cooling radius = 30 kpc

History

- Post-AGB heating considered previously in the context of the *origin* of hot gas in ellipticals
  - Mathews & Baker 1971
  - Lake & Schommer 1984
  - Mathews 1990
  - Brighenti & Mathews 1996, 1997



Conroy & van Dokkum, submitted



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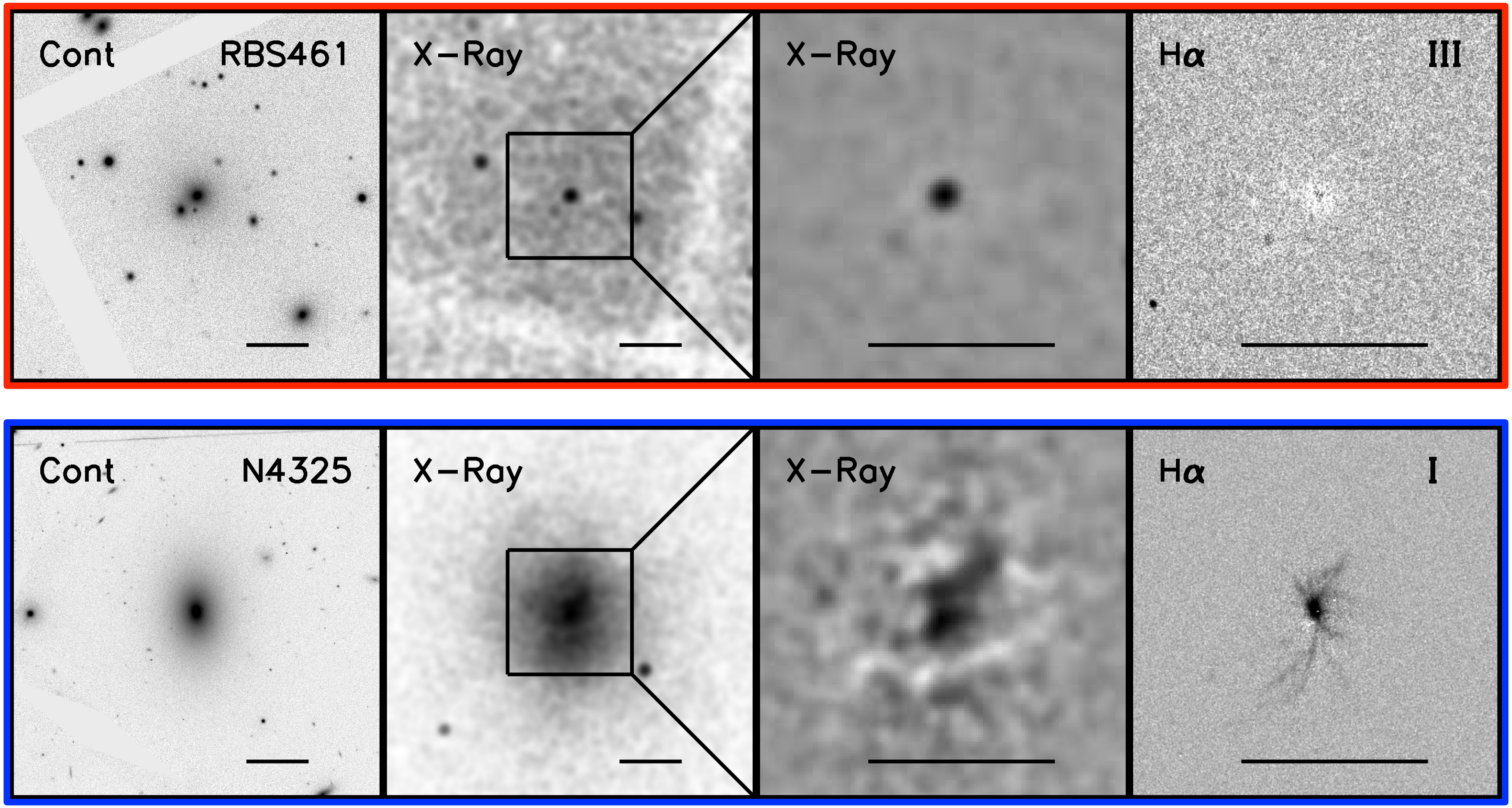
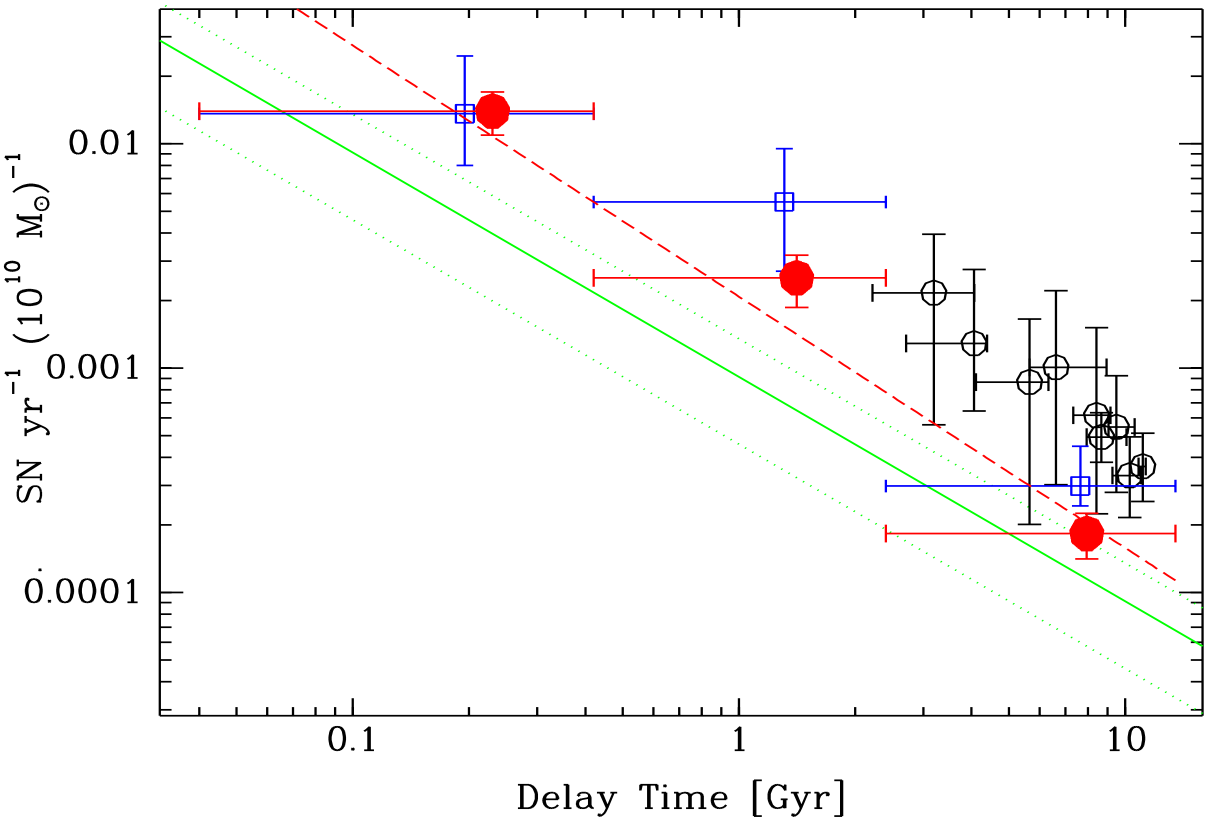


McDonald et al. 2011

Comparison to SNe Ia heating

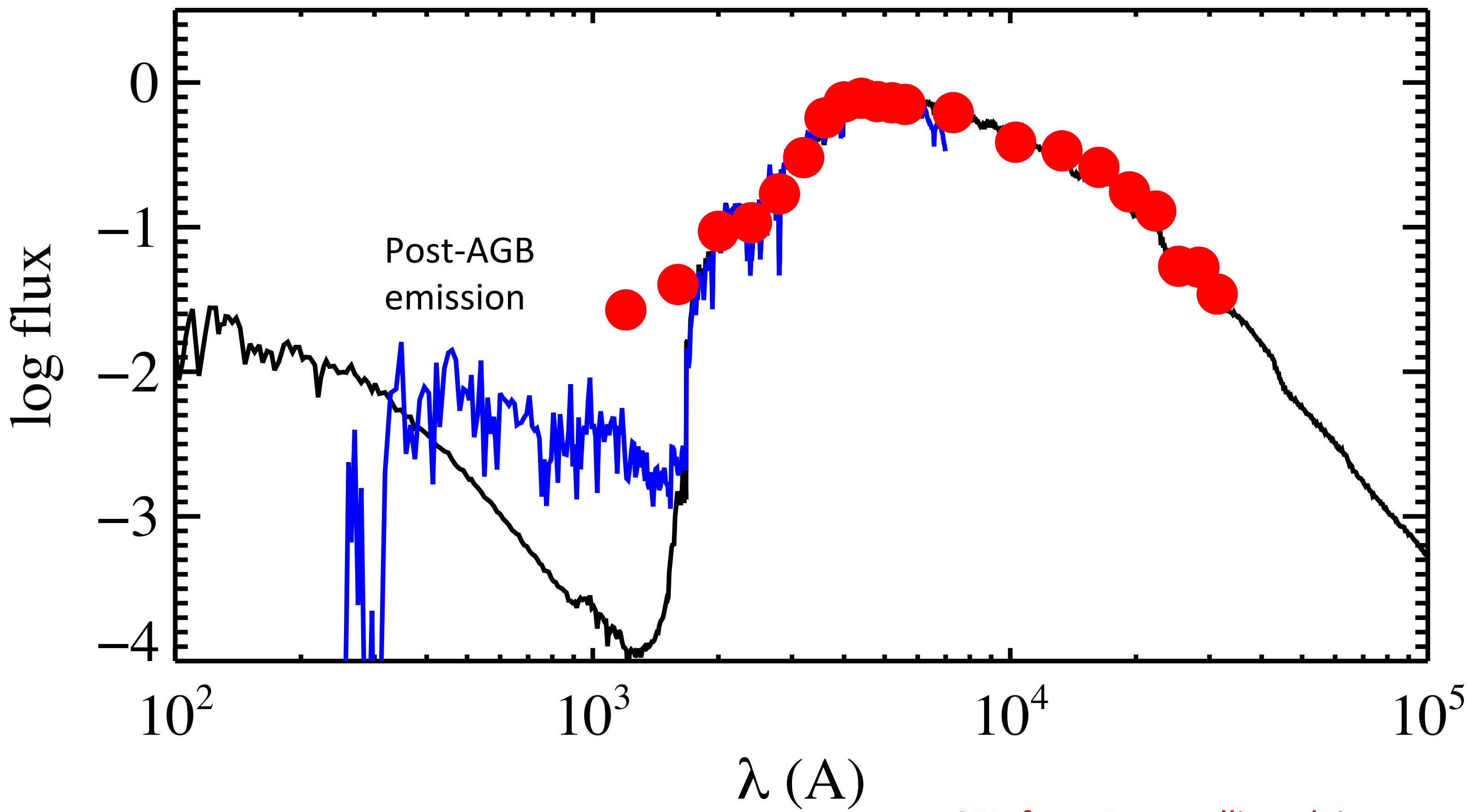
- Heating from SNe Ia's comparable to pAGB stars at z=2
- Order of magnitude smaller at z~0



Maoz et al. 2012

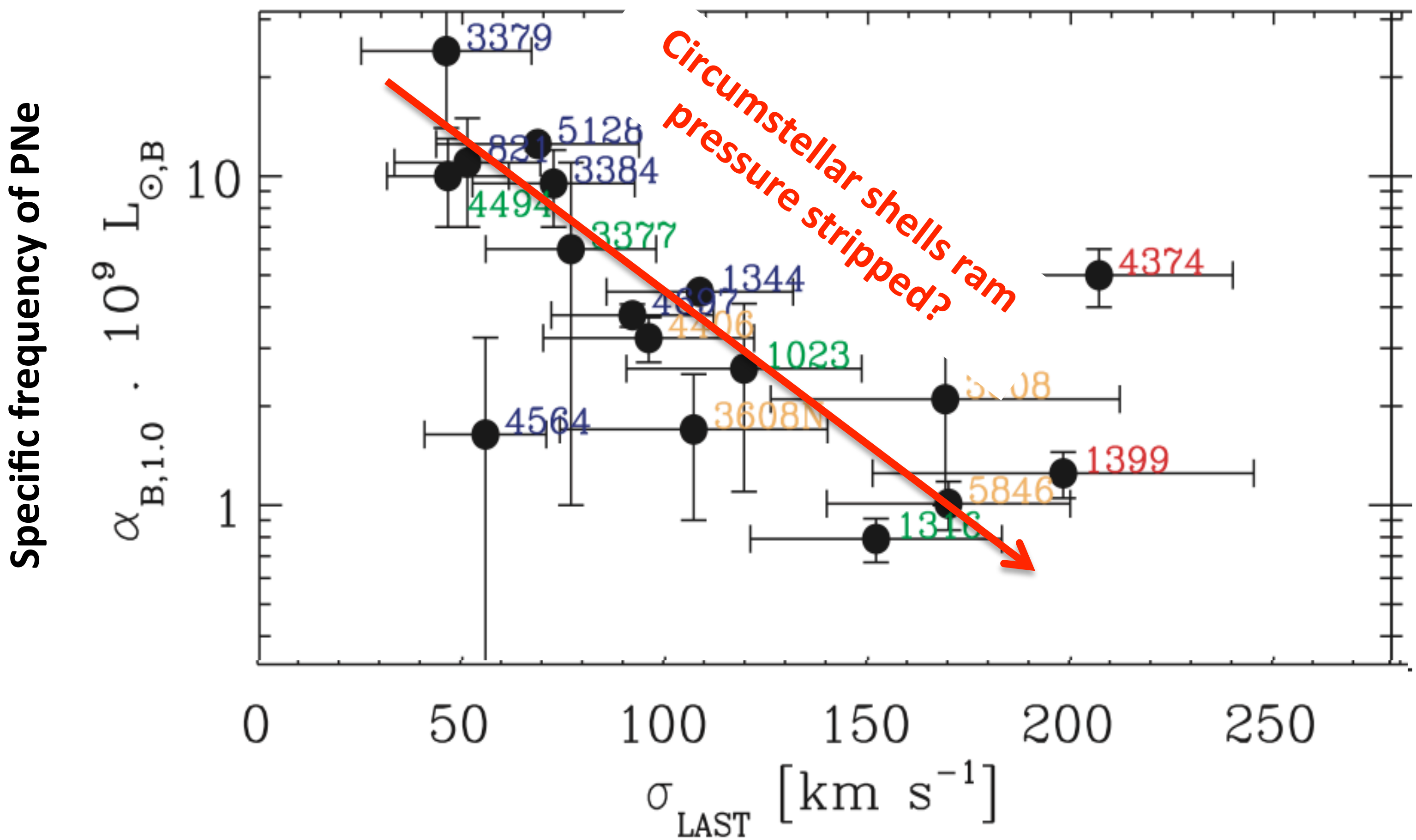
Consistent with observed SEDs at z~2

Stacked SED of quiescent galaxies at z=2



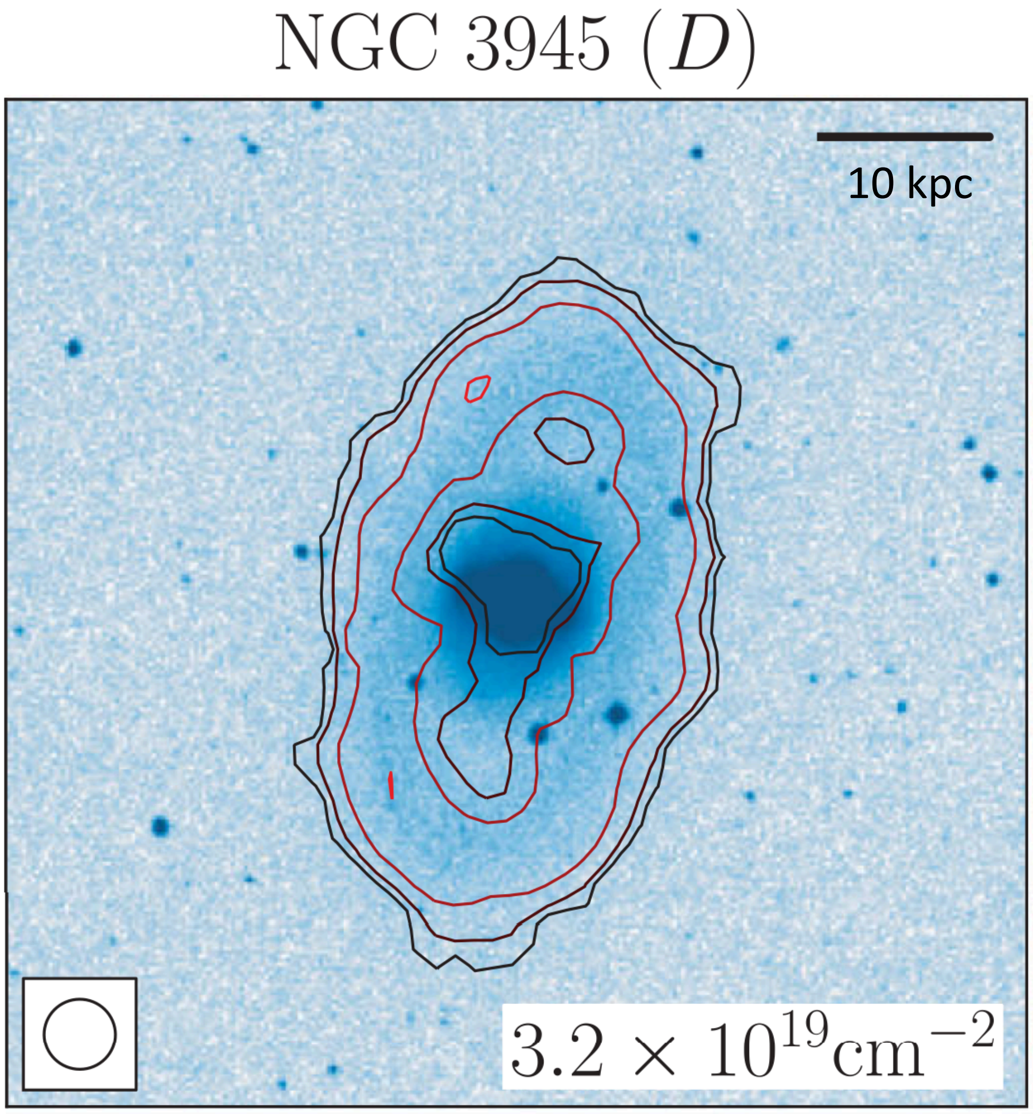
SED from Fumagalli et al. in prep

Planetary Nebulae vs. Galaxy Dispersion



Coccato et al. 2009

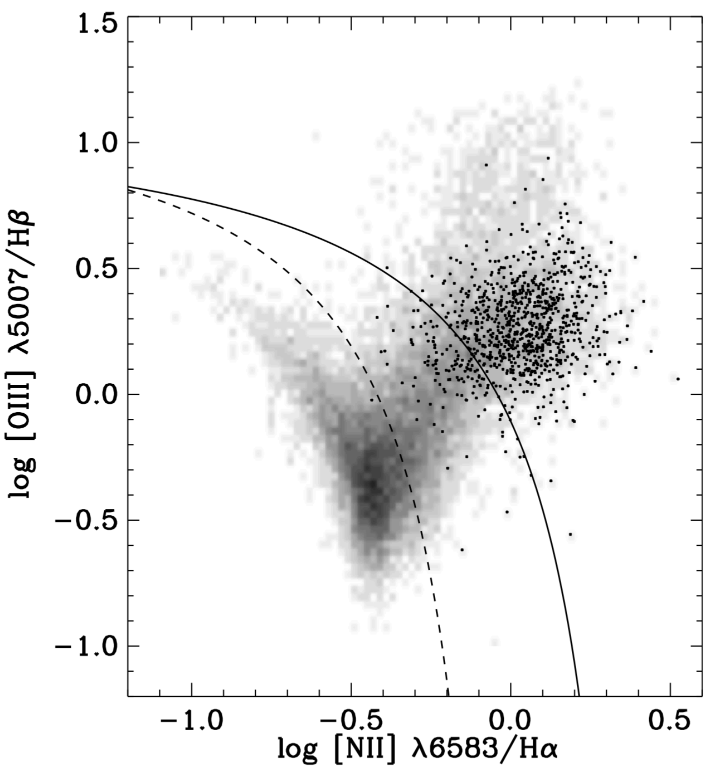
HI Disks in ETGs with no SF: heated by pAGB stars?

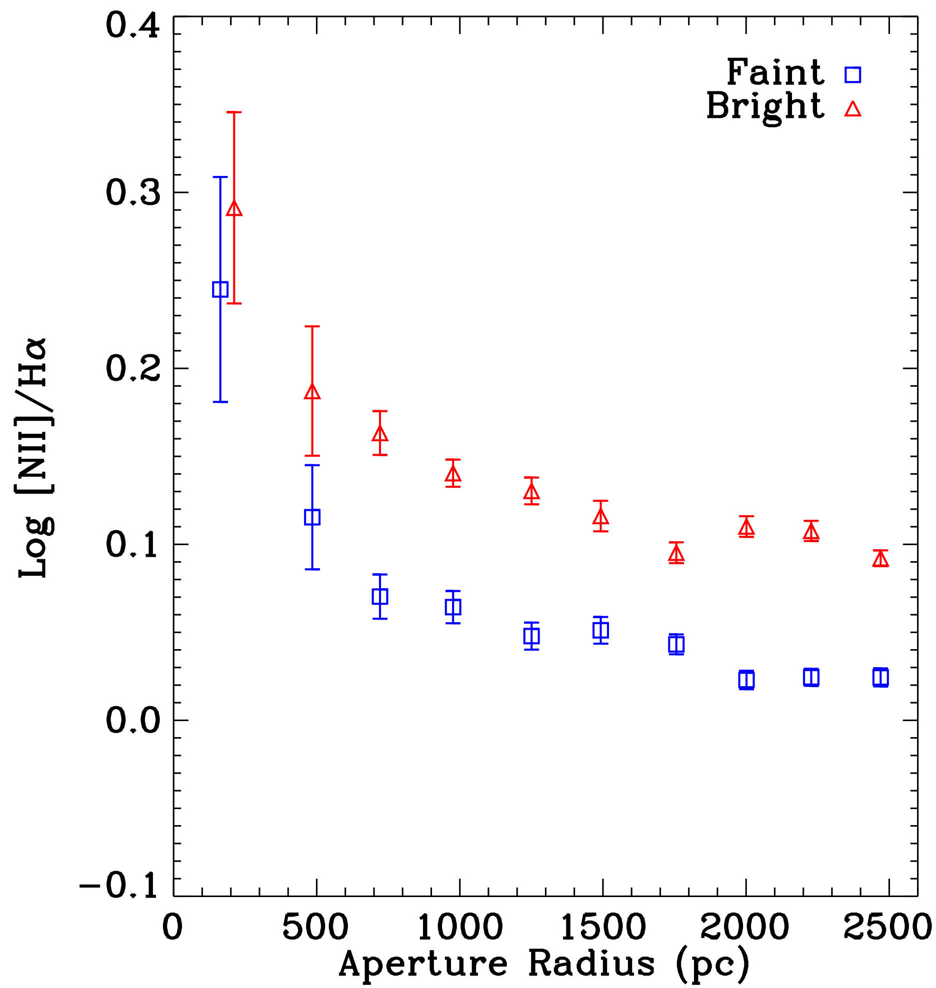


Serra et al. 2012

Spatially-extended Emission Lines in ETGs

- Standard interpretation: emission lines powered by post-AGB stars



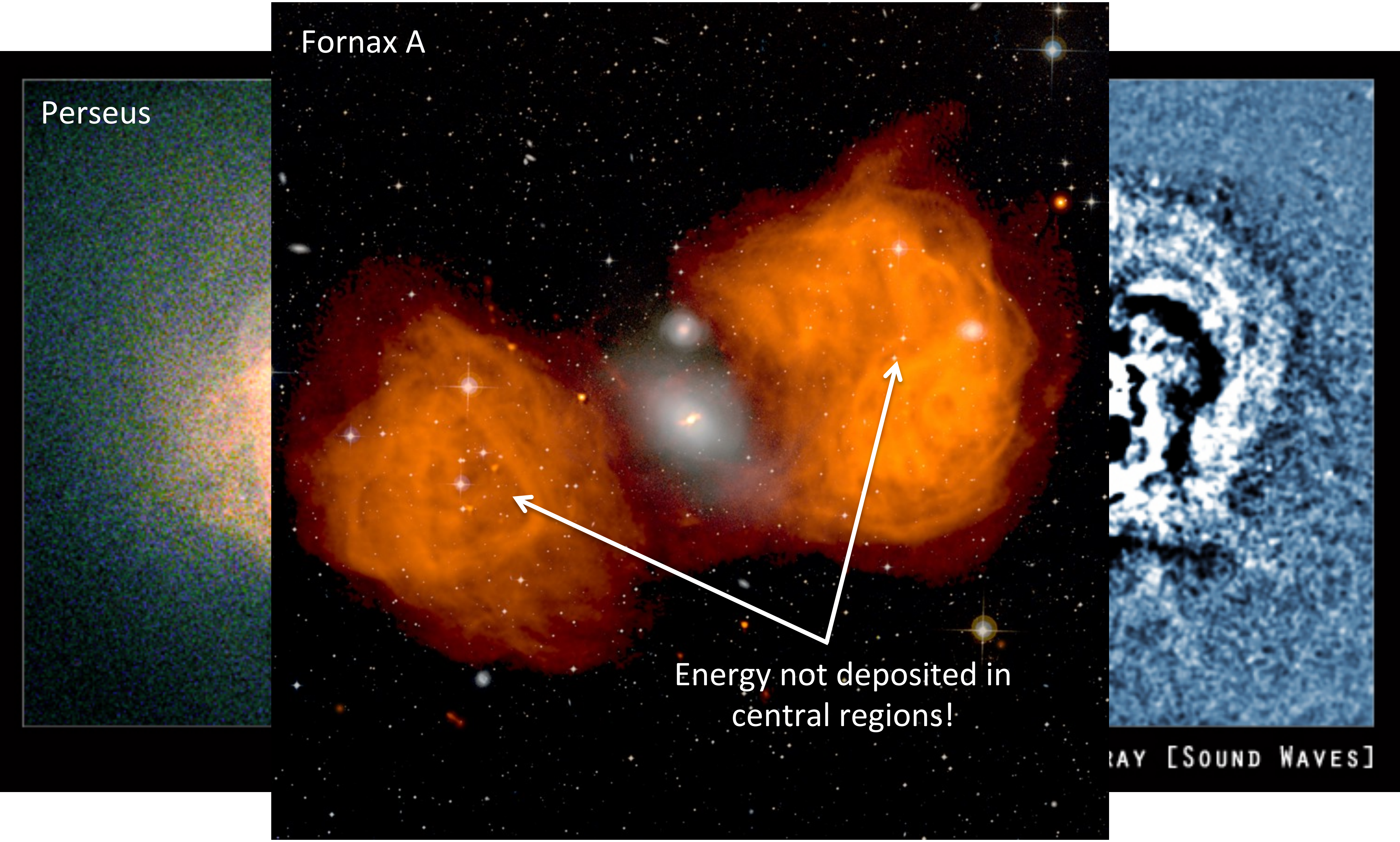


Yan & Blanton 2012

Some Implications & Comments

1. Strong correlation between quenching and stellar density (Σ_1; μ), velocity dispersion (σ)
2. Little intrinsic redshift dependence (but requires a hot halo)
3. No “feedback”, just heating
4. Fewer PNe in central regions of quiescent galaxies; naked UV sources

But: Radio AGN probably do *something!*



Conclusions

1. Stellar heating from post-AGB stars offers a possible alternative to “radio mode” AGN heating
2. This heating source *must exist*, only question is how important in detail
3. Numerous observational implications; easily testable
4. Straightforward to implement into hydro simulations in an approximate way
   – Need to study the interaction of the winds/ionization and diffuse gas in detail (e.g., Bregman & Parriott)
   – Big uncertainty: lifetime of post-AGB phase. Constrainable via observations of nearby galaxies