Morphological quenching

Increased stability for gas disks in early-type galaxies

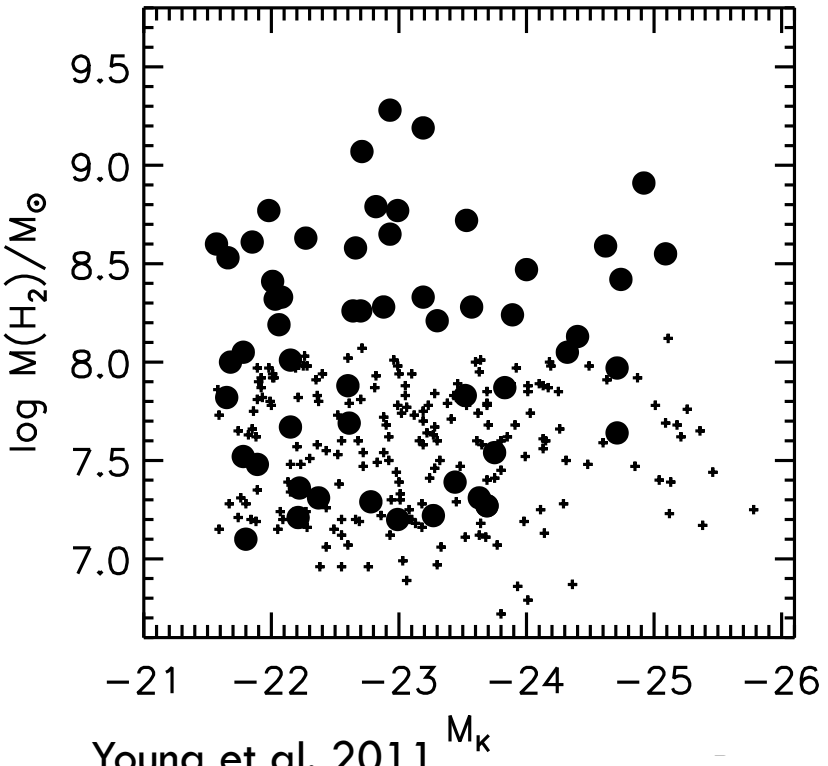
Marie Martig (MPIA)

With :

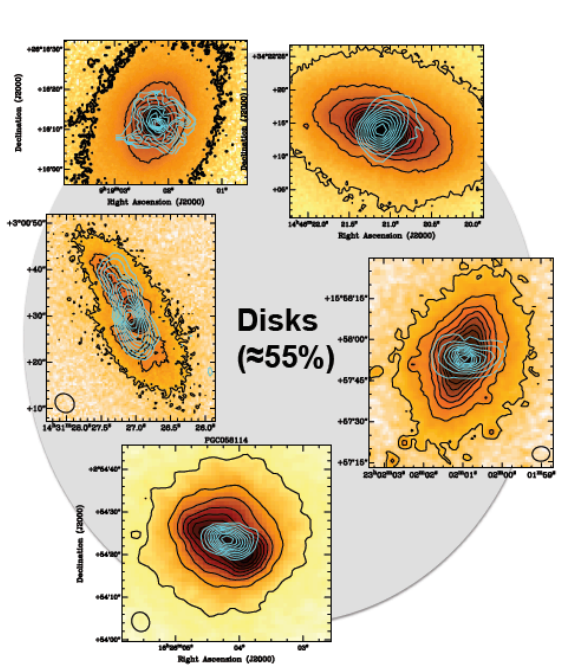
Frederic Bournaud, Avishai Dekel, Romain Teyssier

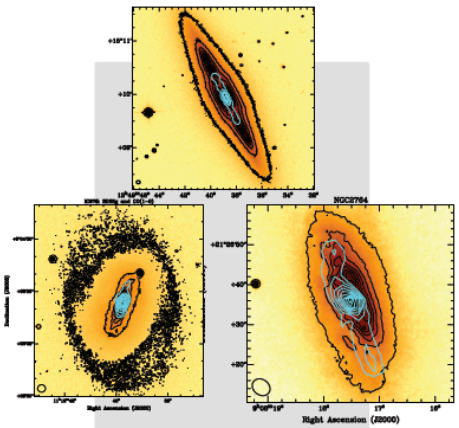
Alison Crocker, Eric Emsellem, Tim Davis, Martin Bureau, Pierre-Alain Duc + ATLAS^{3D}

Gas and star formation in early-type galaxies

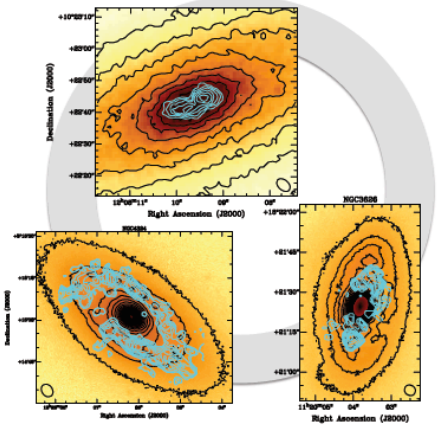


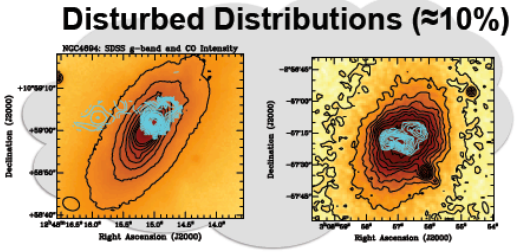
Young et al. 2011





Bars and Rings (≈35%)

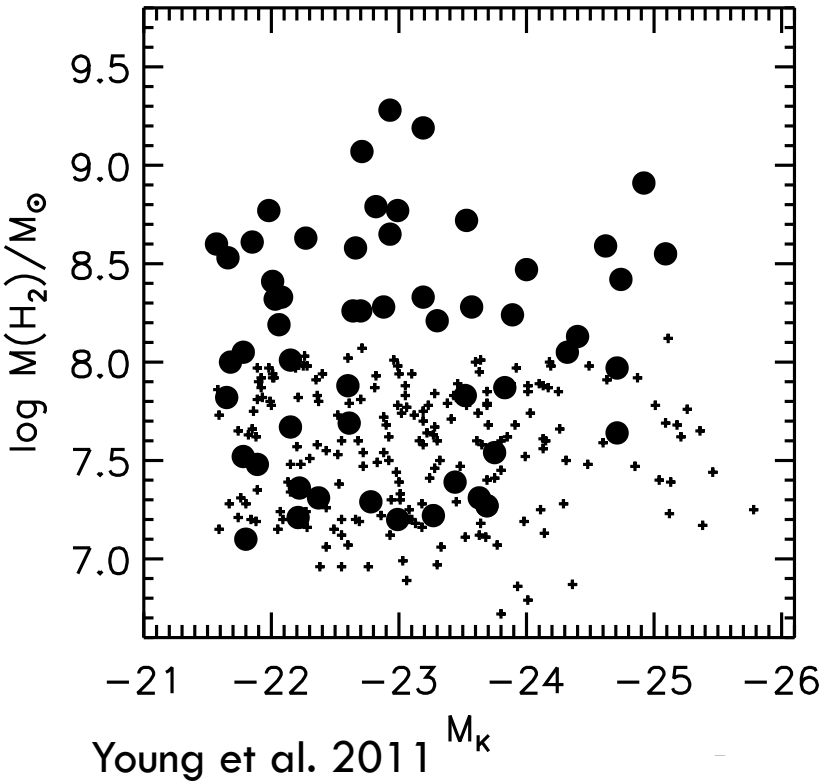




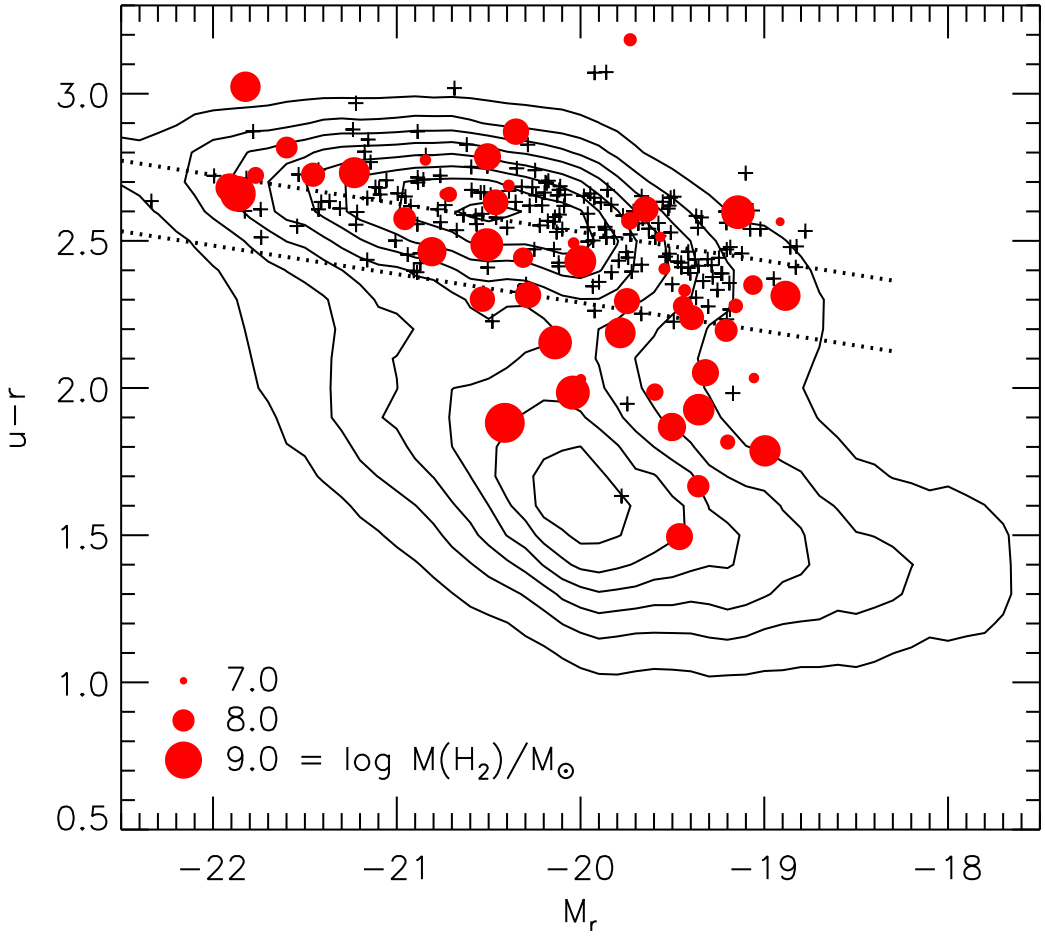
ATLAS^{3D}: volume limited sample of 26 local ETGs
22% detection rate in CO !

See also: Davis et al 2011a,b, 2013, Alatalo et al 2013

Gas and star formation in early-type galaxies



Young et al. 2011



ATLAS^{3D}: volume limited sample of 260 local ETGs

22% detection rate in CO !

Gas disk stability against local collapse and star formation

- Stability results from a competition between:
  - self-gravity
  - velocity dispersion which inhibits the collapse
  - differential rotation that shears gas clouds
- Toomre parameter for a thin rotating gas disk:

$$Q_g = \frac{\kappa \sigma_g}{\pi G \Sigma_g}$$

- Stability criterion: $Q_g > 1$
- For a gas disk embedded in a stellar disk: an effective Toomre parameter (stars contribute to instability)

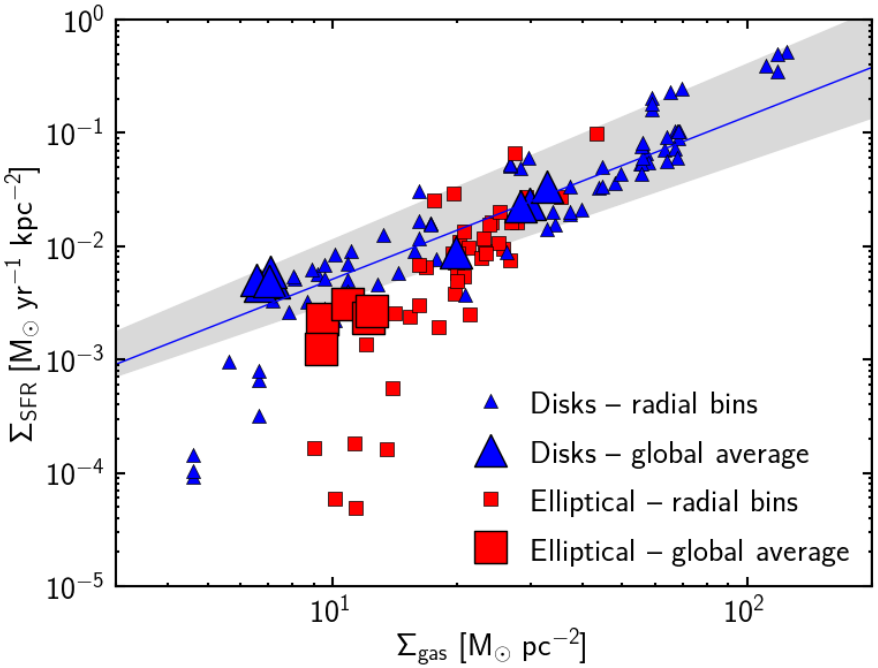
$$\frac{1}{Q} = \frac{1}{Q_g} + \frac{1}{Q_s}$$

Gas disk stability in elliptical galaxies

- Gas disk is stabilized when stars are in a spheroid instead of a disk:
  - steeper potential well
  - reduced disk self-gravity

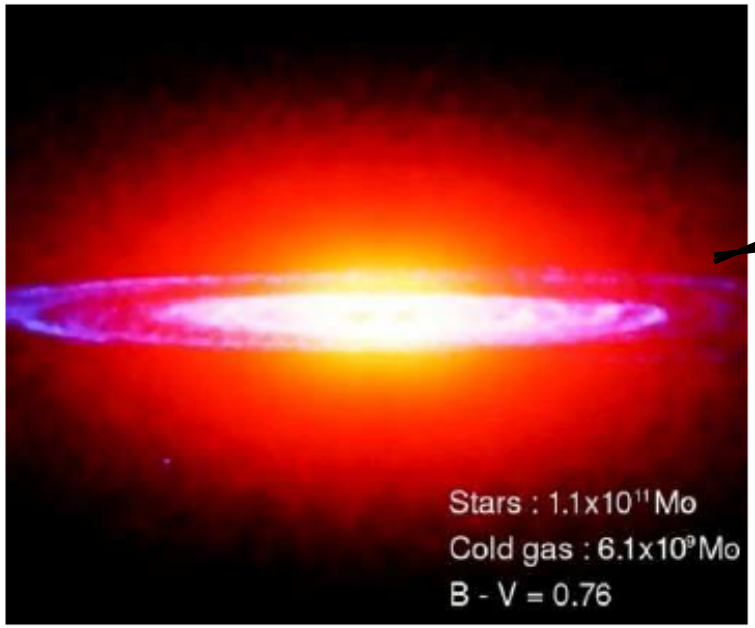
ETGs should have lower star formation efficiencies:

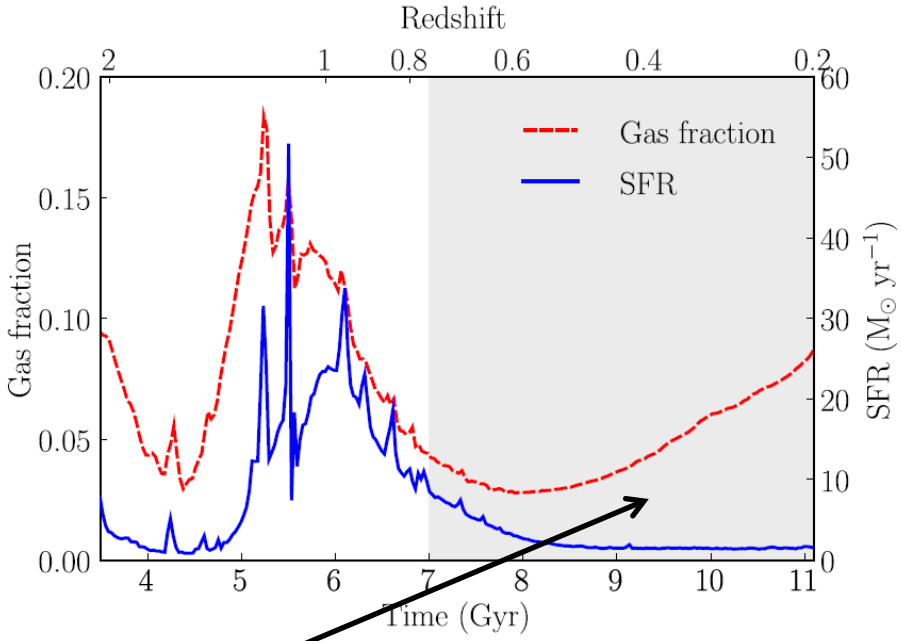
morphological quenching (Martig et al. 2009)

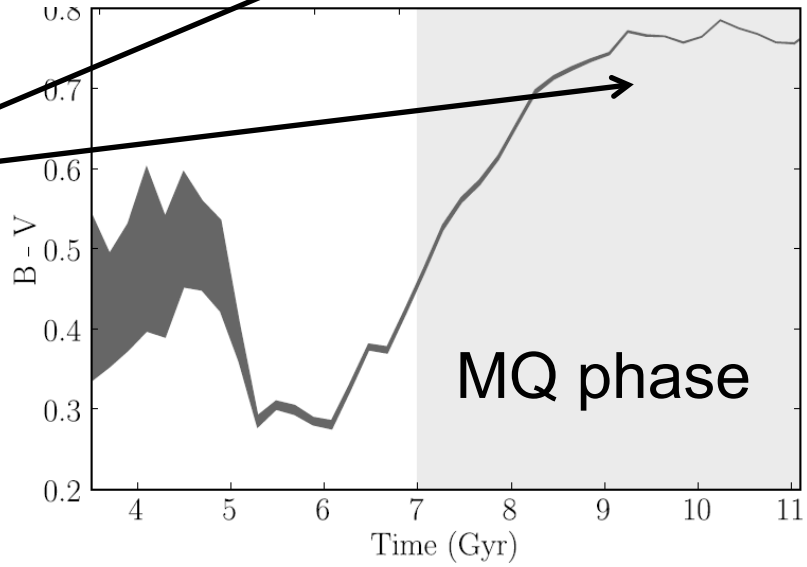


Morphological quenching in a cosmo simulation

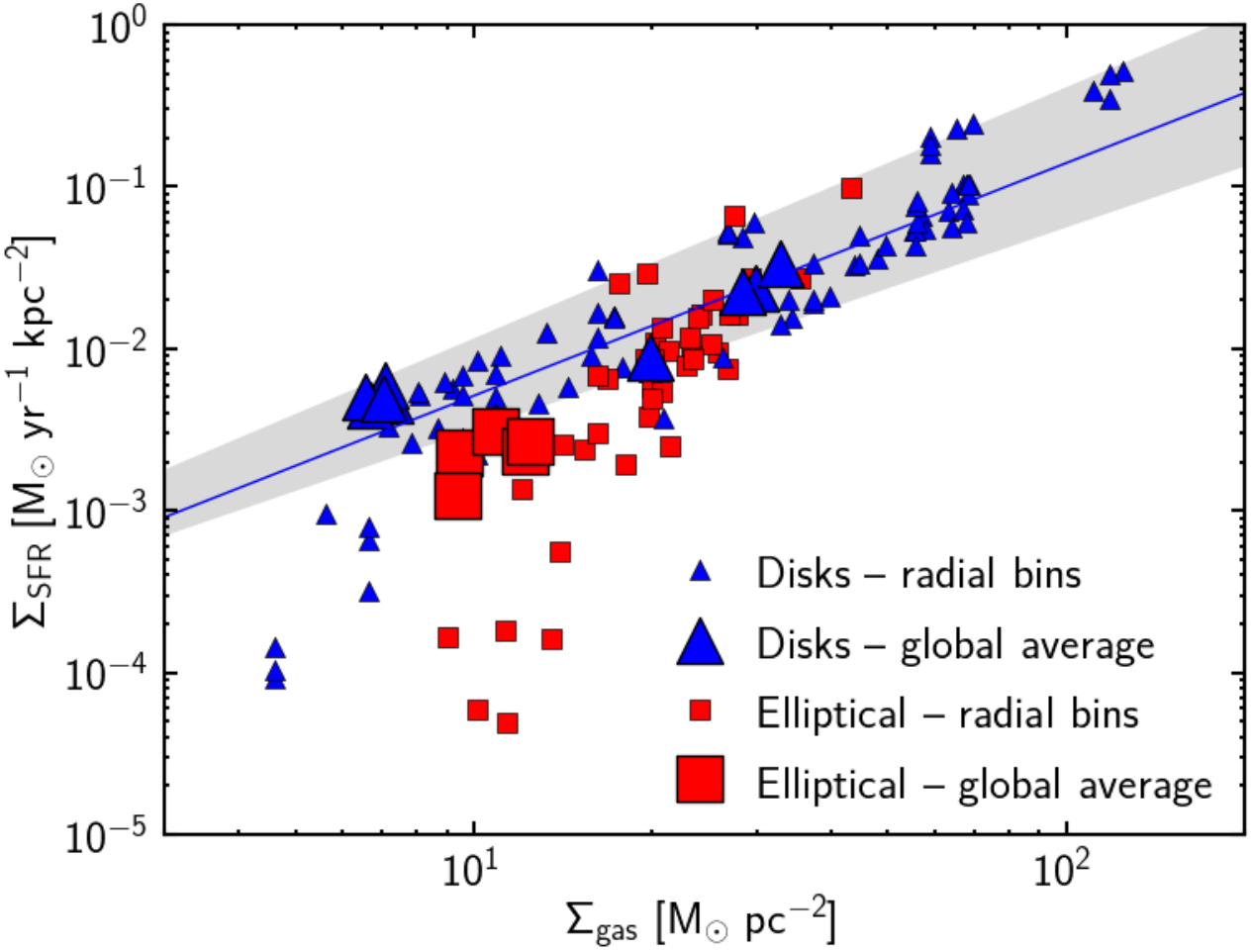
Elliptical galaxy with a massive gas disk but inefficient SF and red colors (Martig et al. 2009)





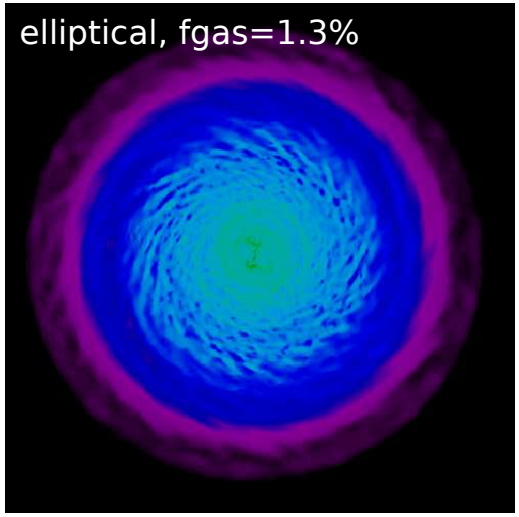


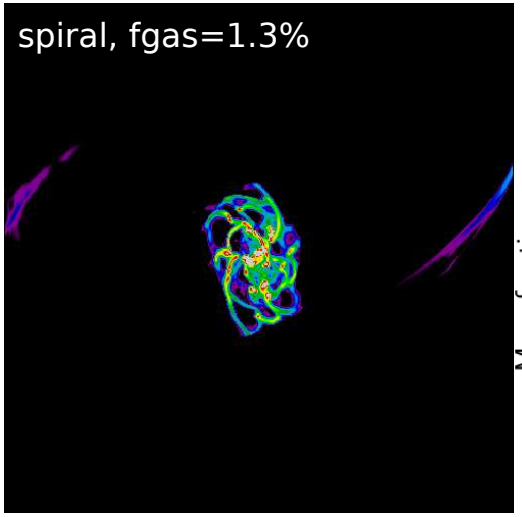
Lower SF efficiency in elliptical galaxies



A comparison with high resolution AMR simulations

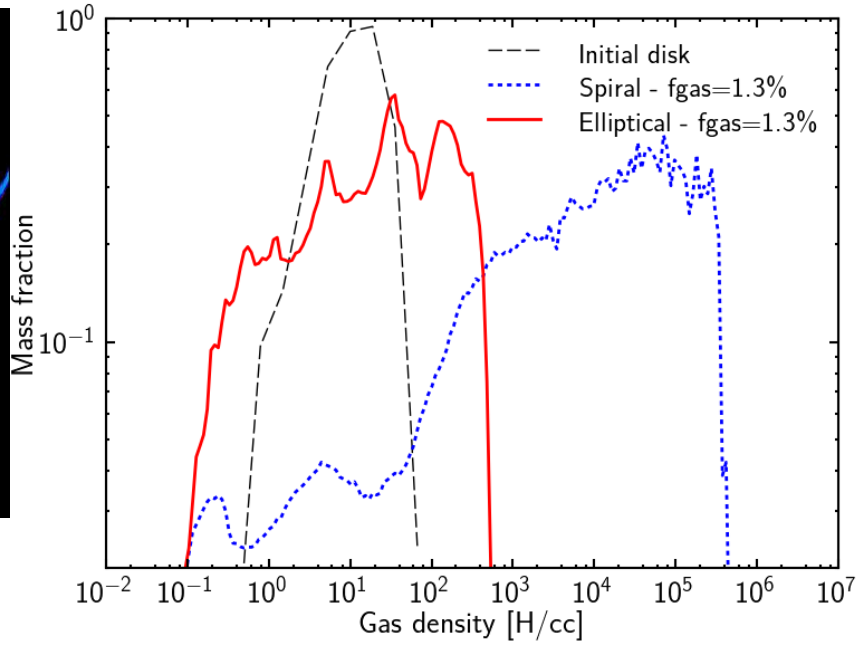
- AMR code RAMSES, 5 pc maximal resolution, star formation, kinetic SN feedback (Martig, Crocker et al. 2013)
- Same gas disk embedded in spiral or elliptical galaxy
- M_{gas}=7.5 x 10^8Msun, f_{gas}=1.3%





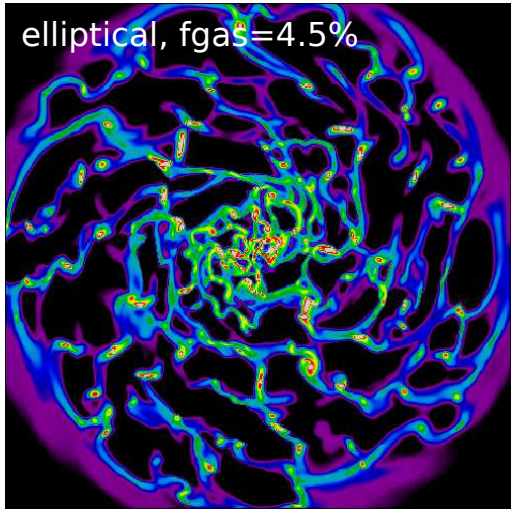
SFR = 0.1 Msun/yr

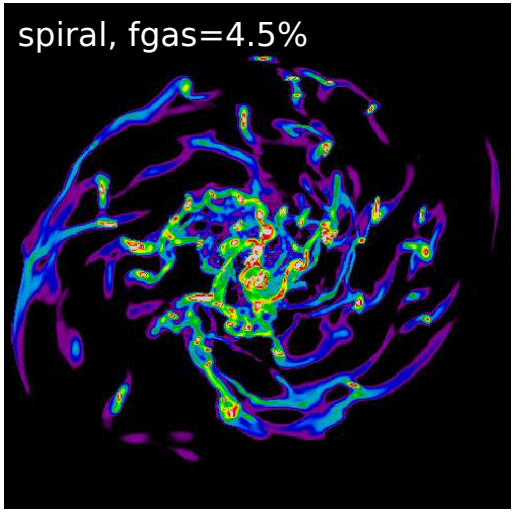
SFR = 2.5 Msun/yr



A comparison with high resolution AMR simulations

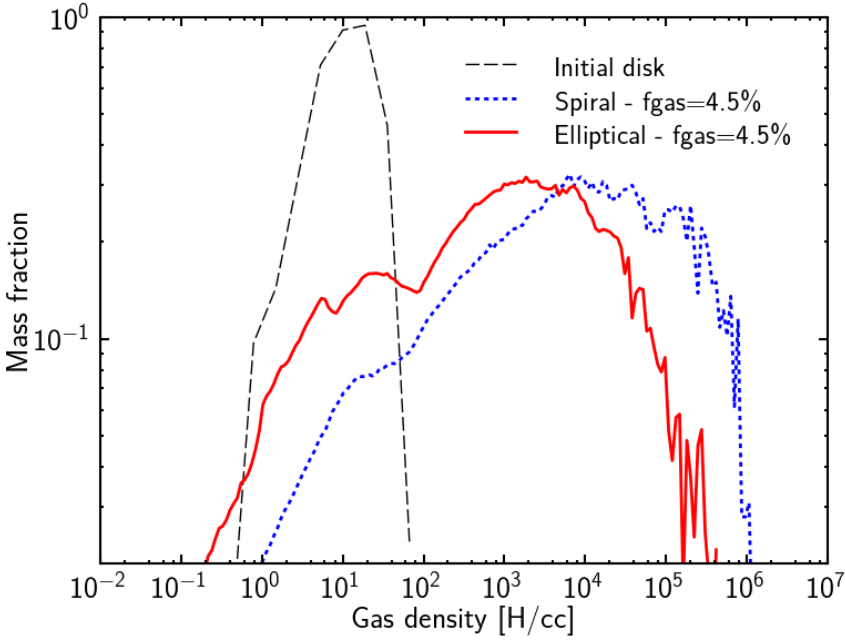
- AMR code RAMSES, 5 pc maximal resolution, star formation, kinetic SN feedback
- Same gas disk embedded in spiral or elliptical galaxy
- M_{gas}=2.5 x 10^9Msun, f_{gas}=4.5%



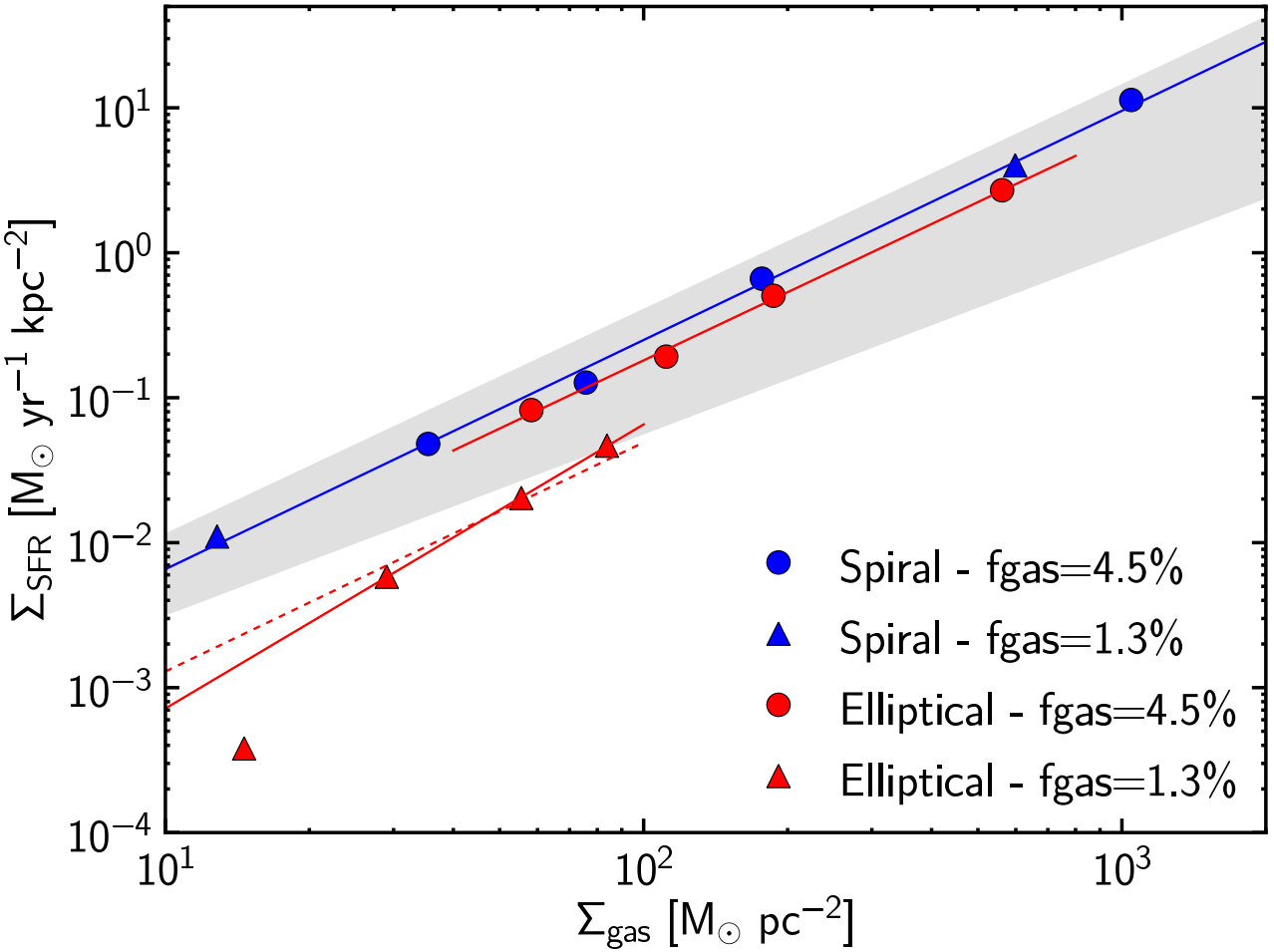


SFR = 4.8 Msun/yr

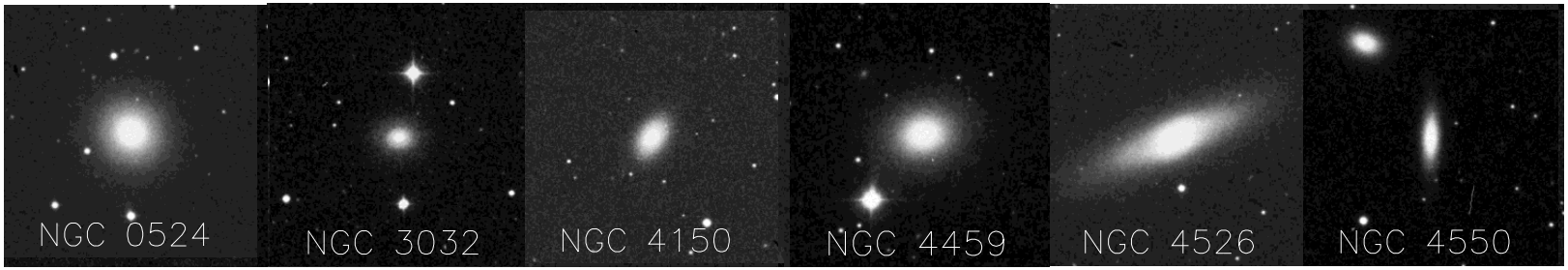
SFR = 11.3 Msun/yr



The resulting Kennicutt relation



Resolved observations of molecular gas and star formation in ETGs



Name	Distance (Mpc)	H_2 mass $\log(M_\odot)$
NGC 524	23.3	7.8
NGC 2768	21.8	7.8
NGC 3032	21.4	8.7
NGC 4150	13.4	7.7
NGC 4459	16.1	8.2
NGC 4477	16.5	7.4
NGC 4526	16.4	8.8
NGC 4550	15.5	6.9

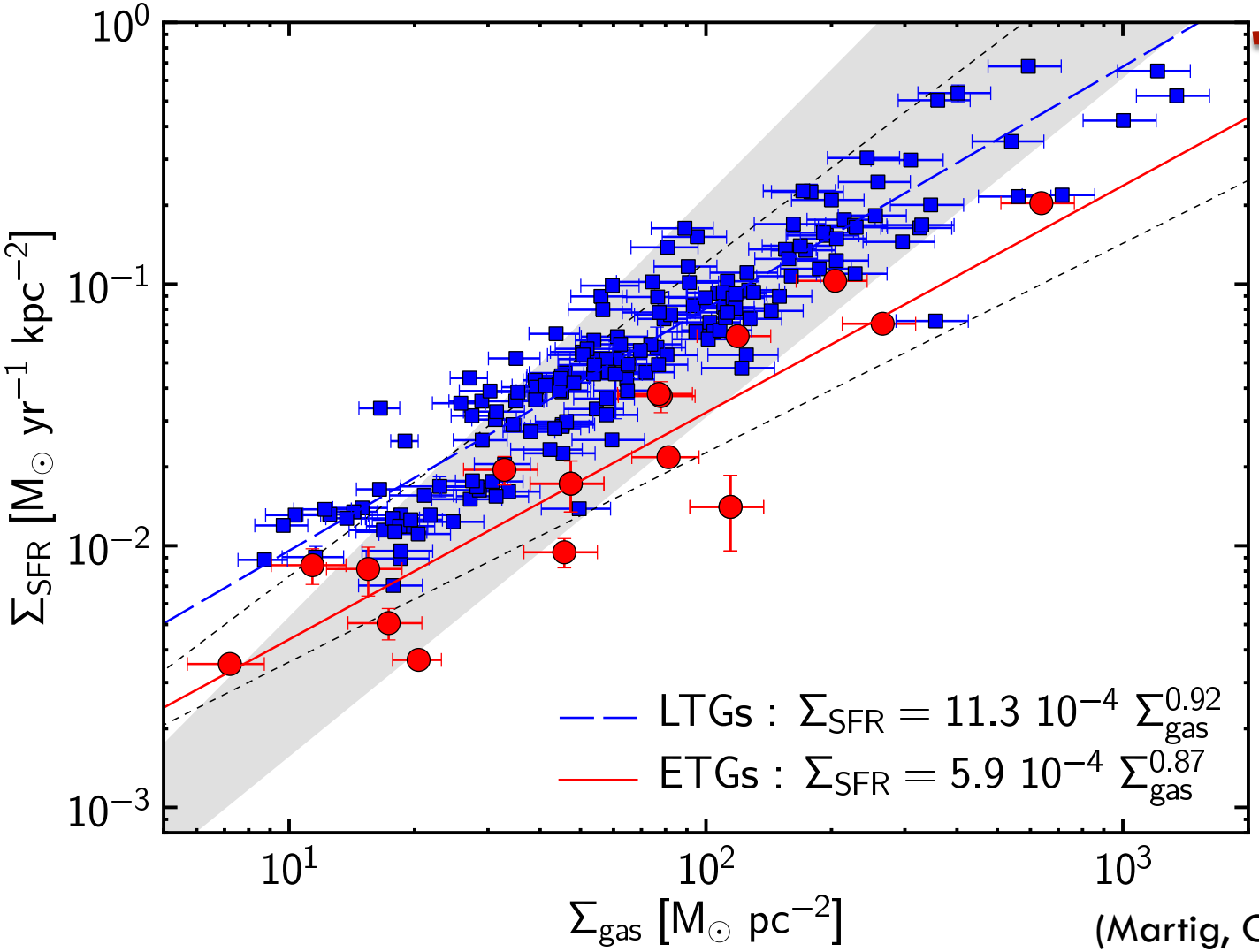
CO maps : BIMA (Young et al. 2008) and PdBI (Crocker et al. 2009,2011)

HI mass: Westerbork (Serra et al. 2012)

SFR maps: non-stellar 8 μ m emission (Shapiro et al. 2010)

+12 spirals with data from THINGS (Walter et al. 2008), BIMA-SONG (Helfer et al. 2003) and SINGS (Kennicutt et al. 2003) surveys

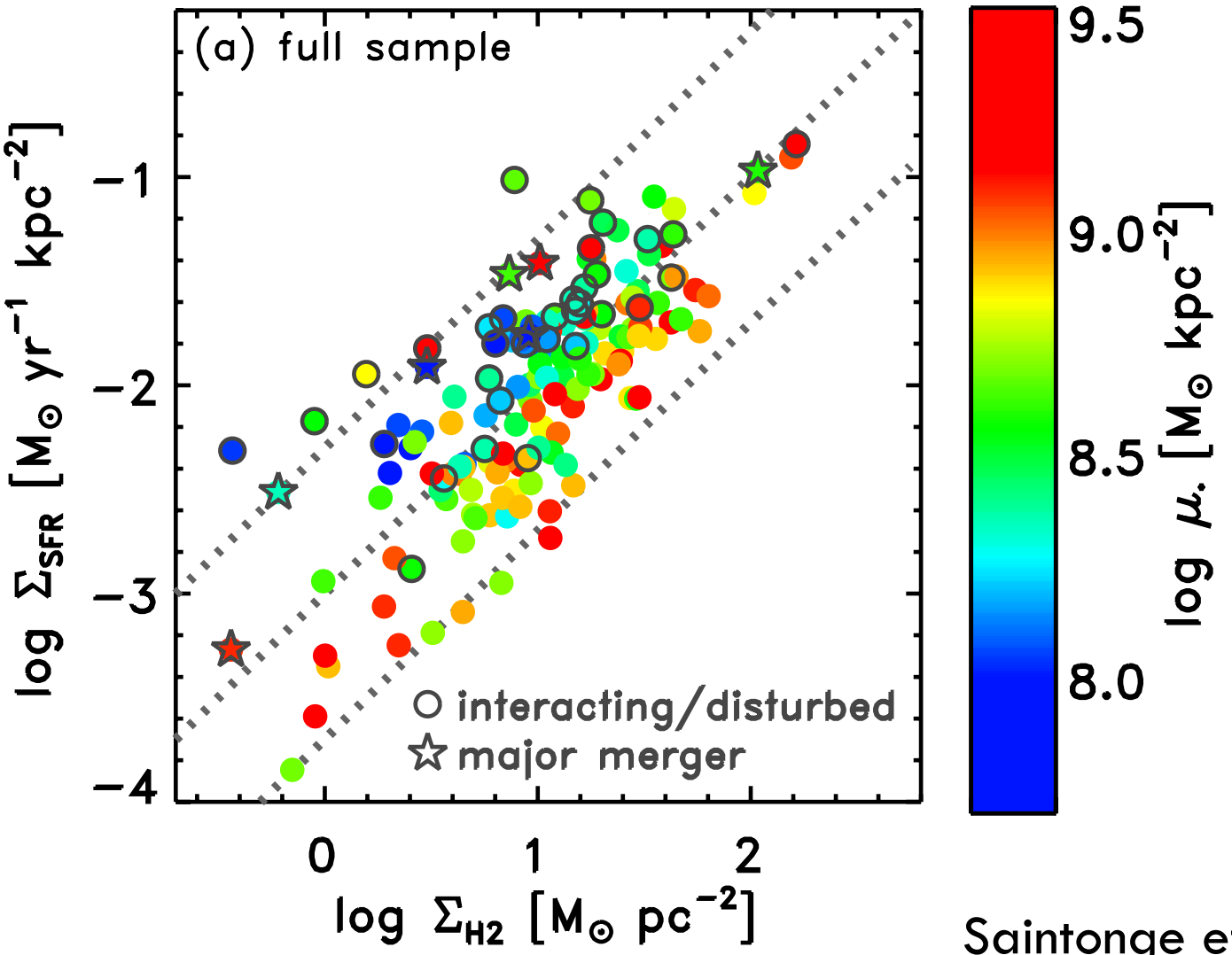
Observed ETGs have a lower star formation efficiency



SF efficiency
~2 x lower

(Martig, Crocker et al. 2013)

Also seen by the COLD GASS survey



Saintonge et al 2012

Conclusion (1)

- Morphological quenching: gas disks are stabilized against star formation when embedded in a stellar spheroid instead of a disk
- Observational and numerical evidence for SF efficiency 2-5 times lower in ETGs
- Enough to make galaxies red
- Caveats:
  - There is an upper limit to the amount of gas that can be stabilized
  - Effect of mergers?

Conclusion (2)

- MQ *could* be *in part* why quenching and bulges are related (Bell et al. 2008, Lang et al. 2014, ...)
- Would make life easier for other mechanisms: no need to totally shut off gas accretion/cooling
- BUT we need molecular gas observations to prove MQ is occurring

WE DO NOT MAKE PREDICTIONS FOR THE GAS CONTENT OF ETGs !!!

If the morphological quenching scenario is correct, then at fixed stellar mass, we would expect to find higher average HI gas fractions for bulge-dominated galaxies on the red sequence than for disk-dominated galaxies on the red sequence. (Fabello et al 2011)