Triggering AGN activity in galaxies: galaxy interactions vs. disk instabilities

Marco Gatti

Bellaterra, 10th February 2016

IFAE Institut de Física d'Altes Energies

Active Galactic Nuclei (AGN)

Compact region situated in the centre of galaxies, characterized by high luminosity, strong variability and by a broad non-stellar spectral energy distribution

powered by accretion onto Super Massive Black Holes (SMBHs)

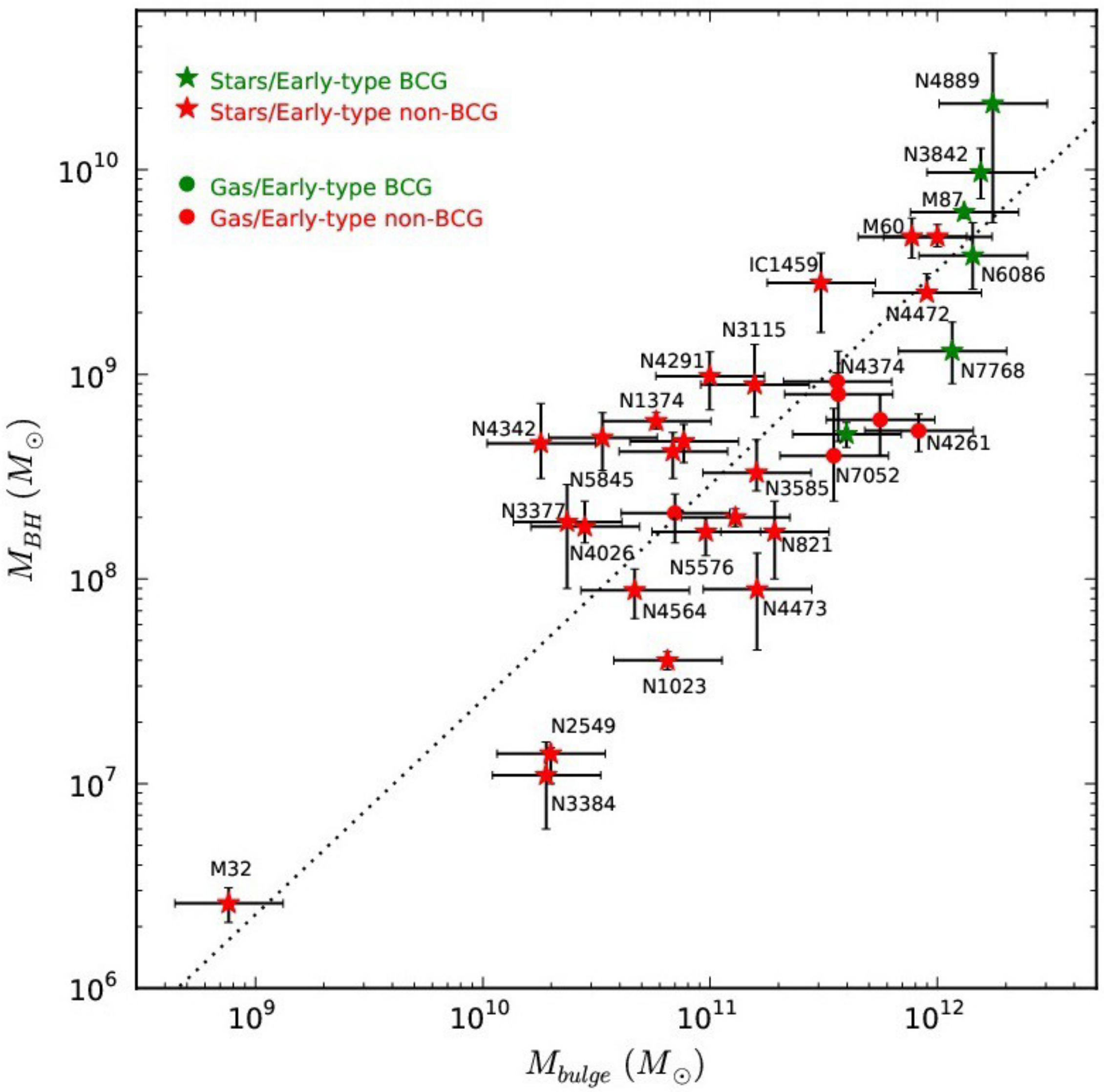
$$M_{BH} \approx 10^6 - 10^9\, M_\odot$$

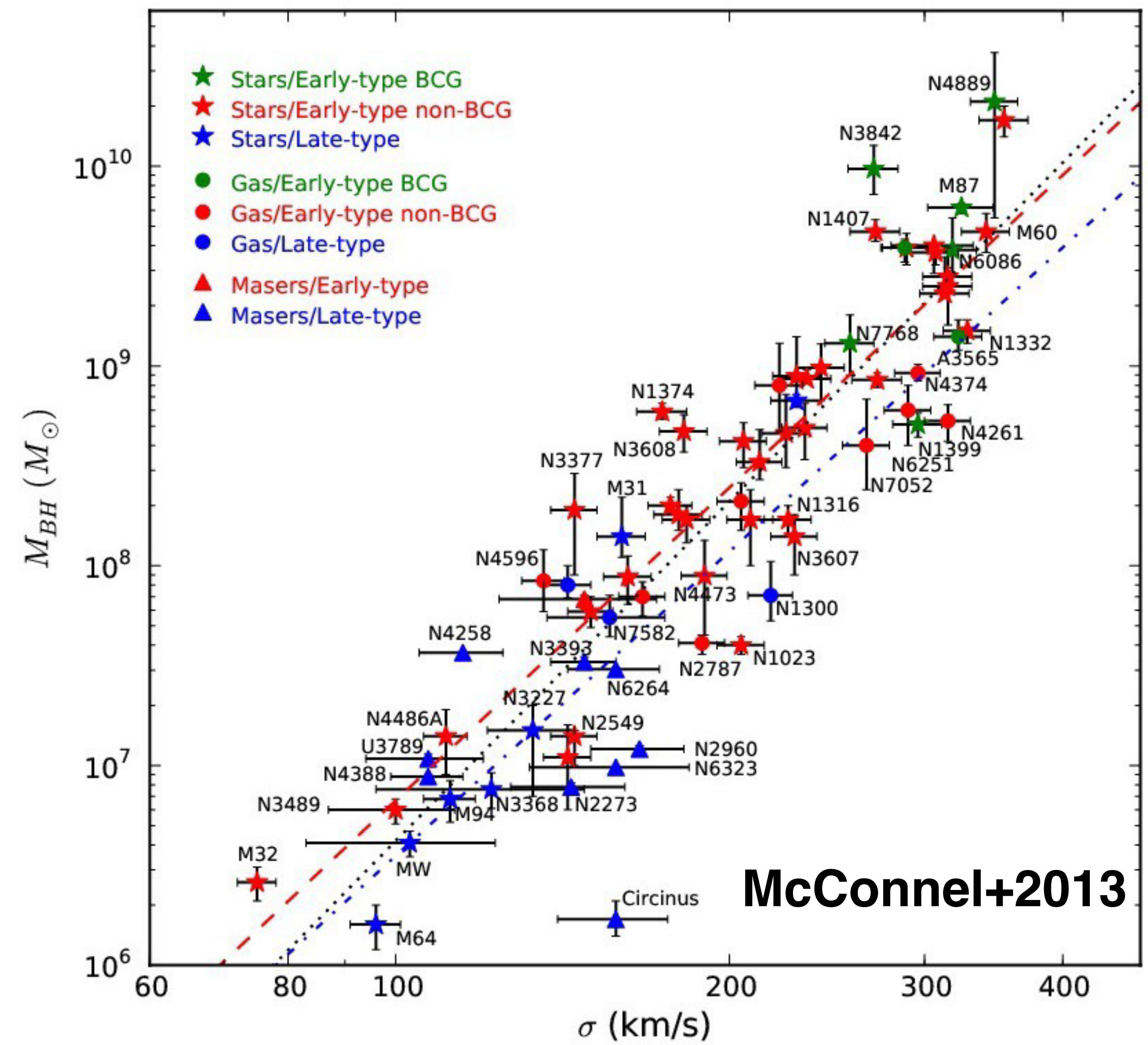
$$L_{Bol} \approx 10^{41} - 10^{48}\, erg\, s^{-1} > L_{gal}$$

$$\text{Variability} \approx seconds - years$$

Why is it important to study AGN?

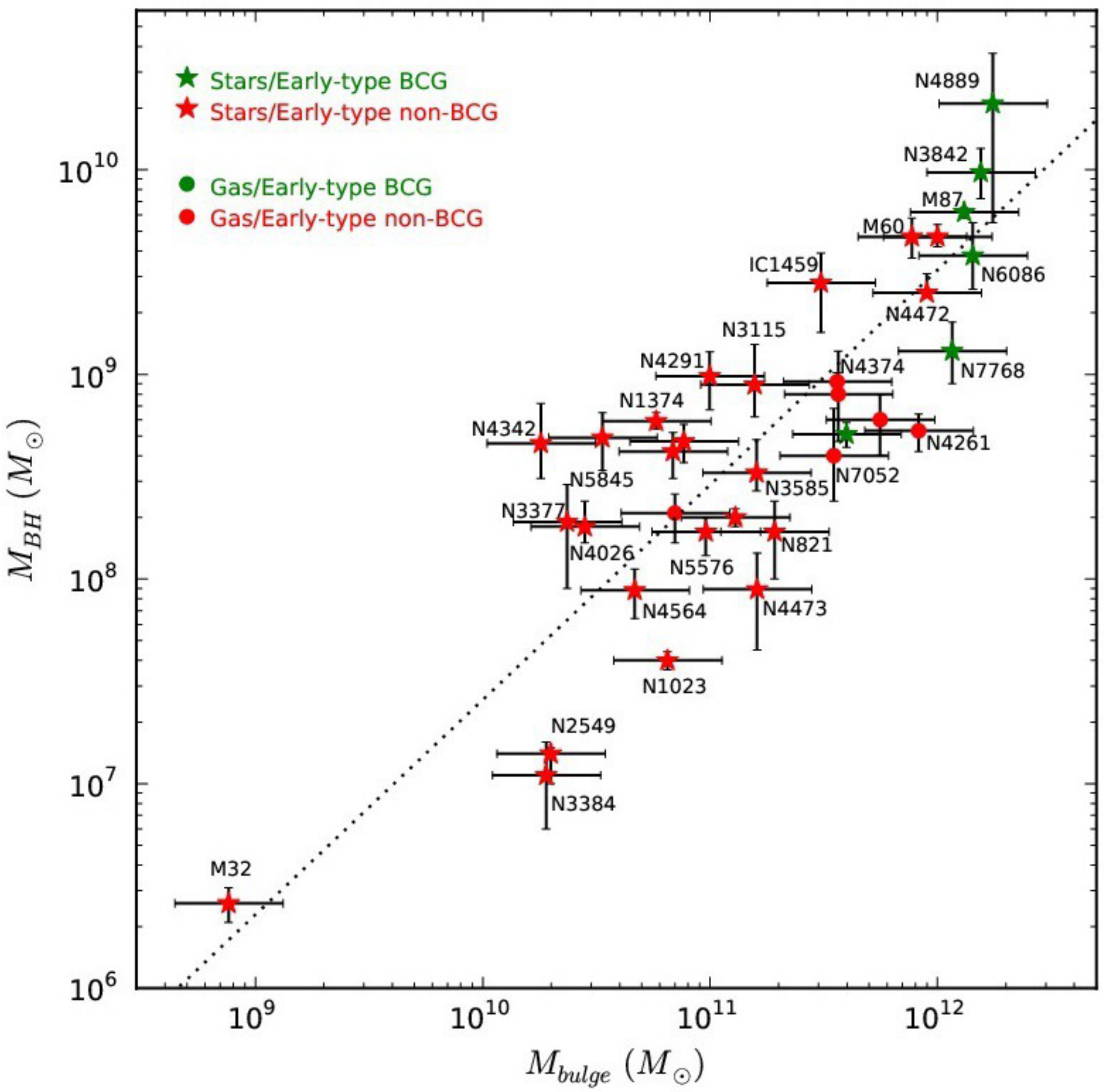
AGN shape the properties of the galaxy population!

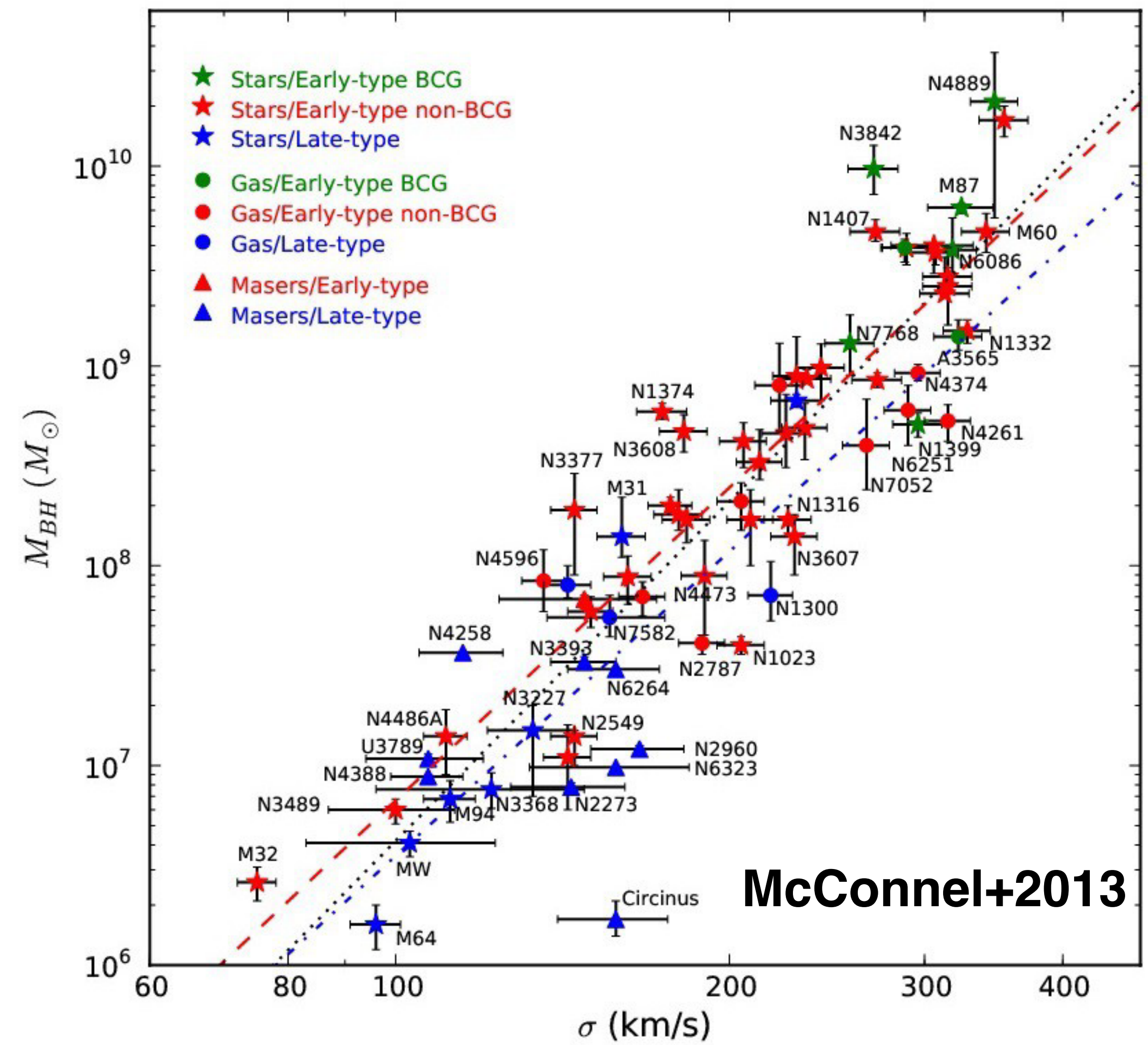




Why is it important to study AGN?

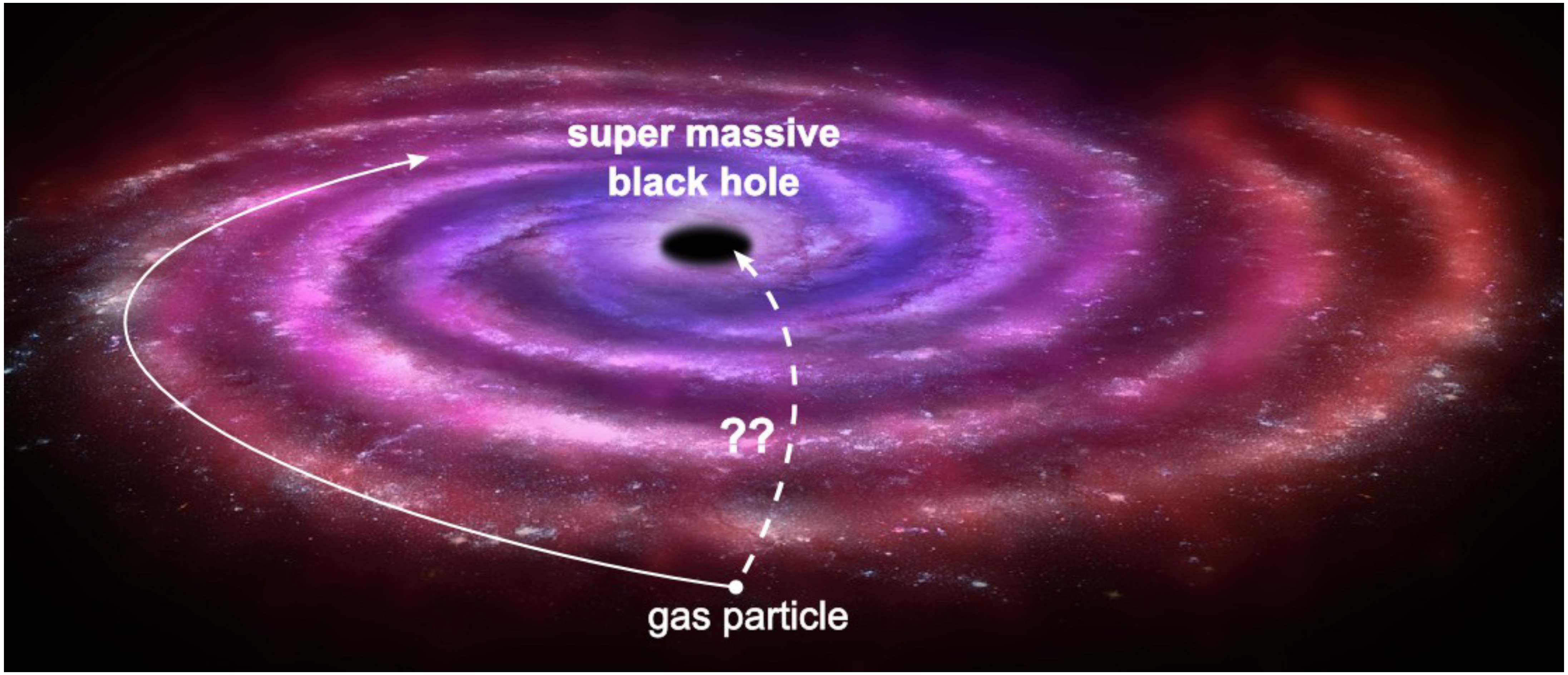
AGN shape the properties of the galaxy population!





? **triggering mechanism(s) responsible for SMBHs accretion and observed relations SMBH-galaxy (bulge)** **?**

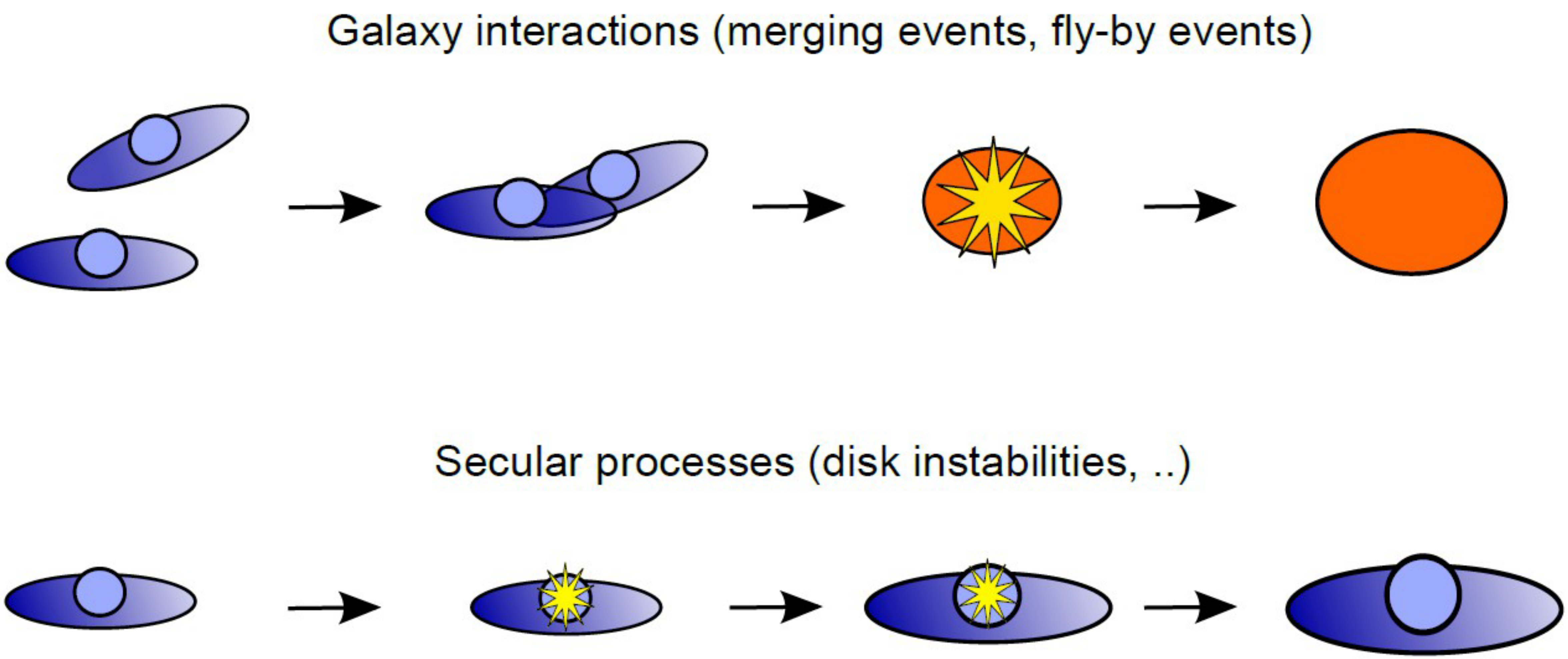
Major problem: angular momentum conservation



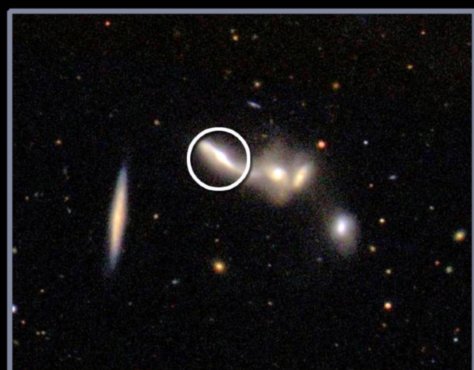
Typical BH accretion rate: 0.001 -10 $M_{\odot}\ yr^{-1}$
Galaxy gas content: up to $10^{10}\ M_{\odot}$

from 10 kpc galactic scales down to sub-pc scales
gas has to lose more than 99.99 % of its angular momentum to be effectively accreted. (Jogee, 2006).

Major problem: angular momentum conservation

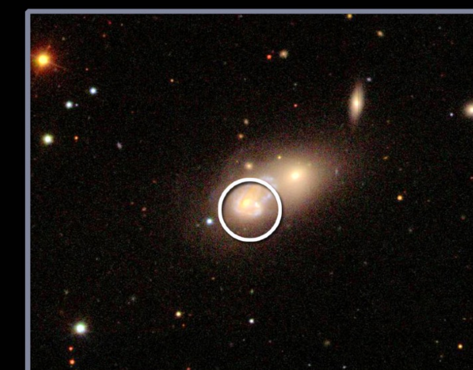


Swift-detected Active Black Holes in Merging Galaxies

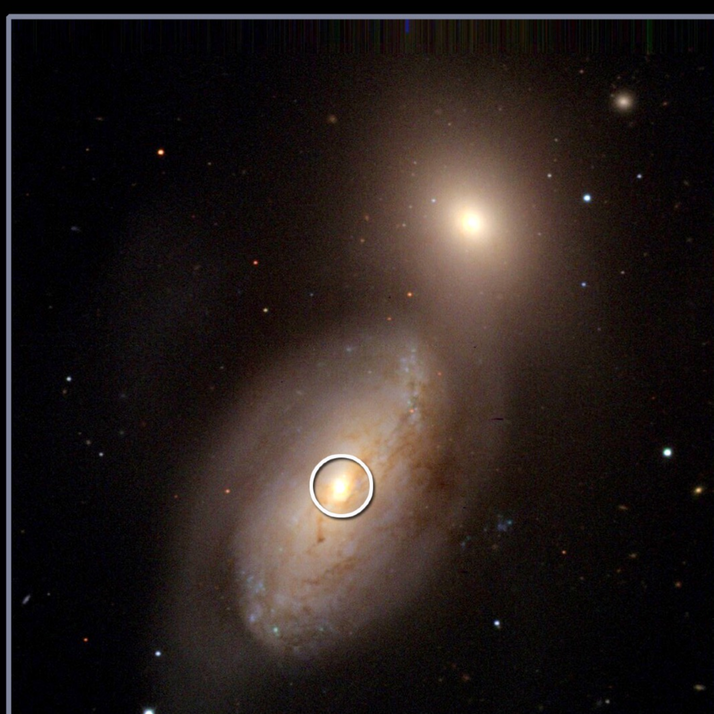


UGC 06527

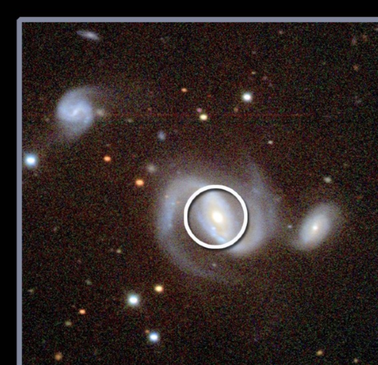
NGC 7319



NGC 1142



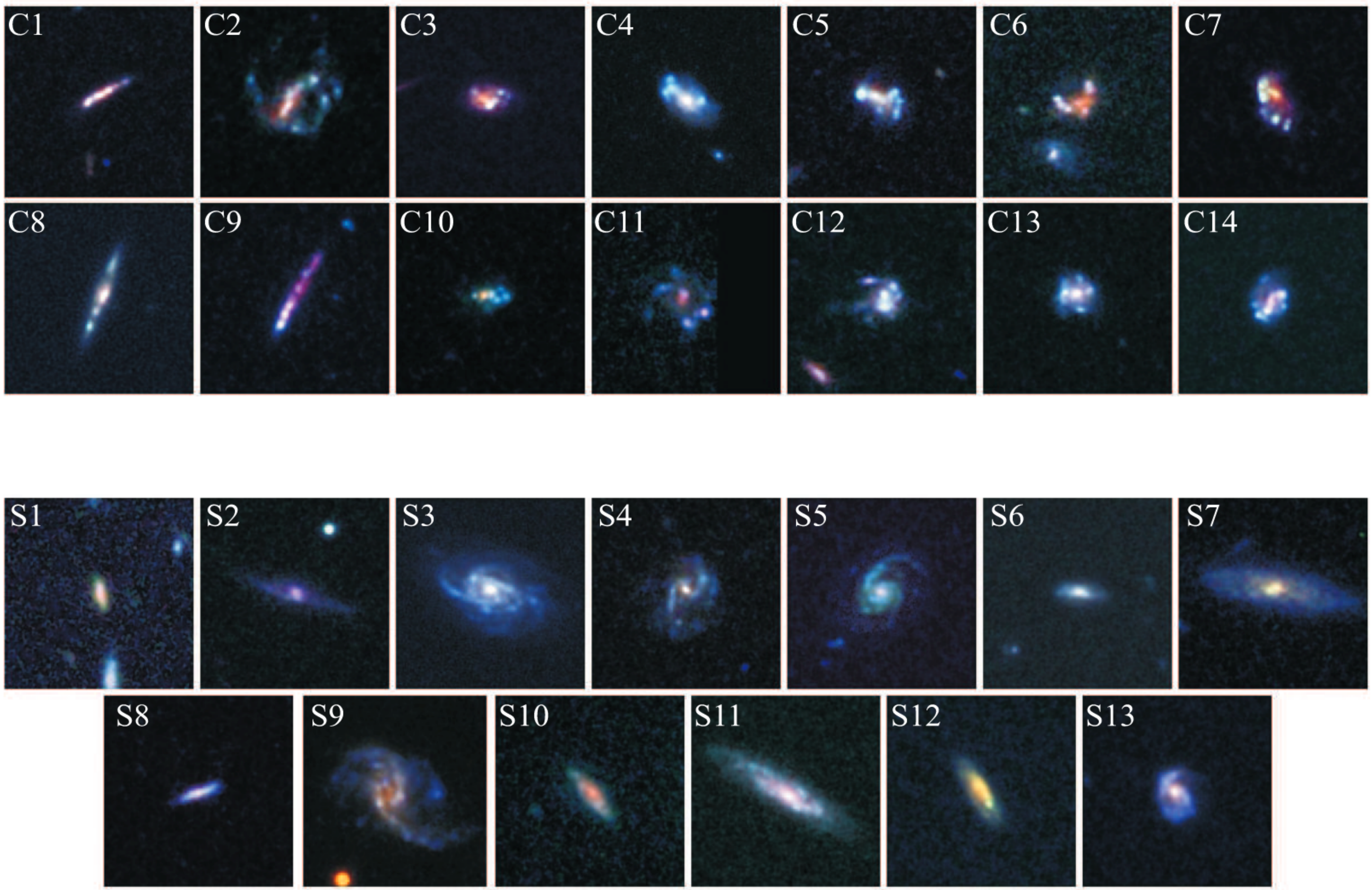
NGC 3227



MCG 0212050

NGC 2992

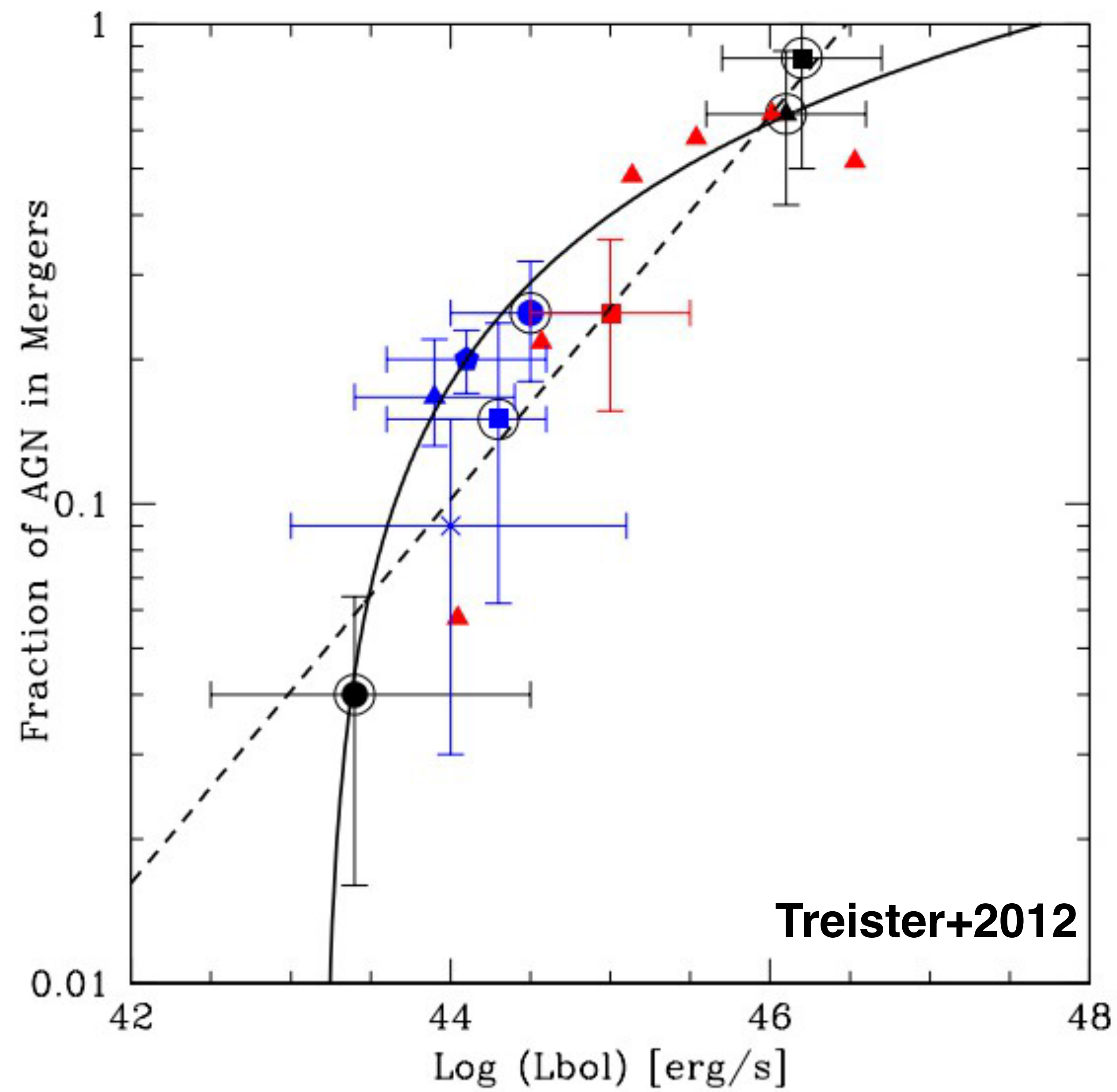
AGN are also detected in isolated galaxies..



A complex observational situation...

Correlation between **strong galaxy interactions** and very **luminous QSOs**
(Disney+1995; Villar-Martn 2010; 2012; Treister+2012…)

…but **moderately luminous AGN might be not major-merger driven**
(Georgakakis+2009; Villforth+2014, Bournaud+2012..)



Observational evidences for both scenarios but still no indication of the dominant mechanism

Semi Analytic Model (SAM) of galaxy formation

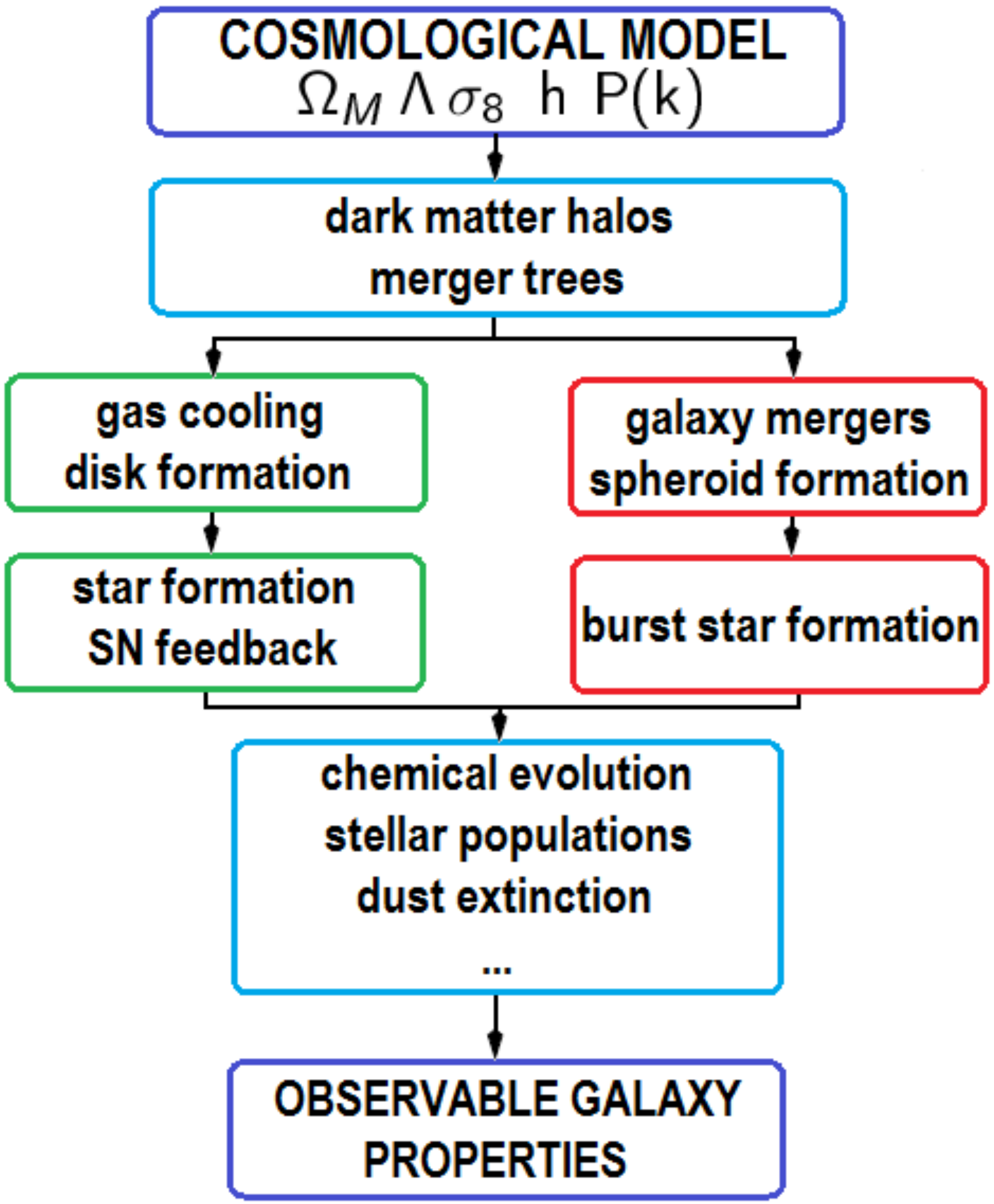
Enables a statistical study about the role of different AGN triggering mechanisms!

(Menci+2004,2006,2008,2014)

Semi Analytic Model (SAM) of galaxy formation

Enables a statistical study about the role of different AGN triggering mechanisms!

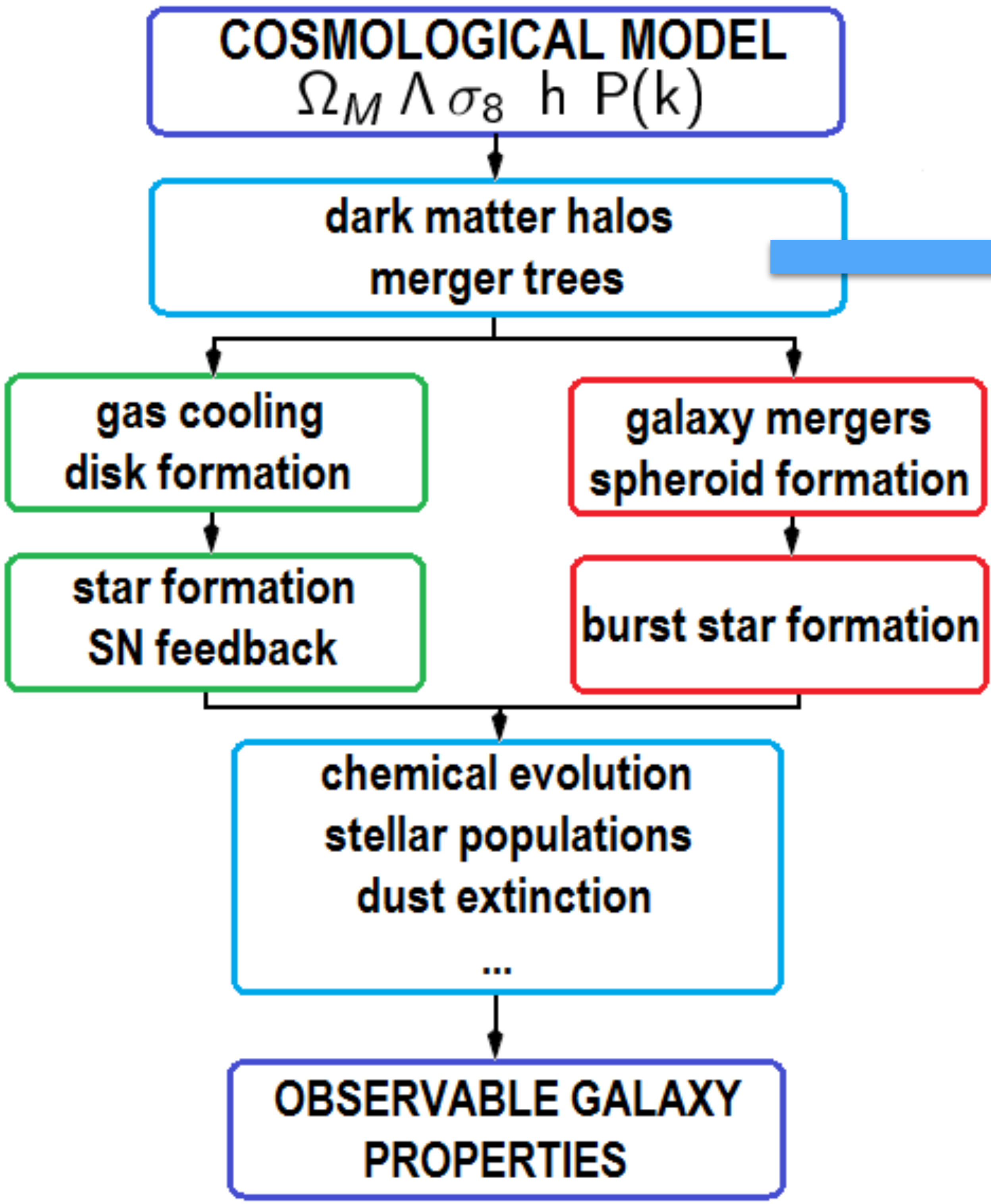
(Menci+2004,2006,2008,2014)

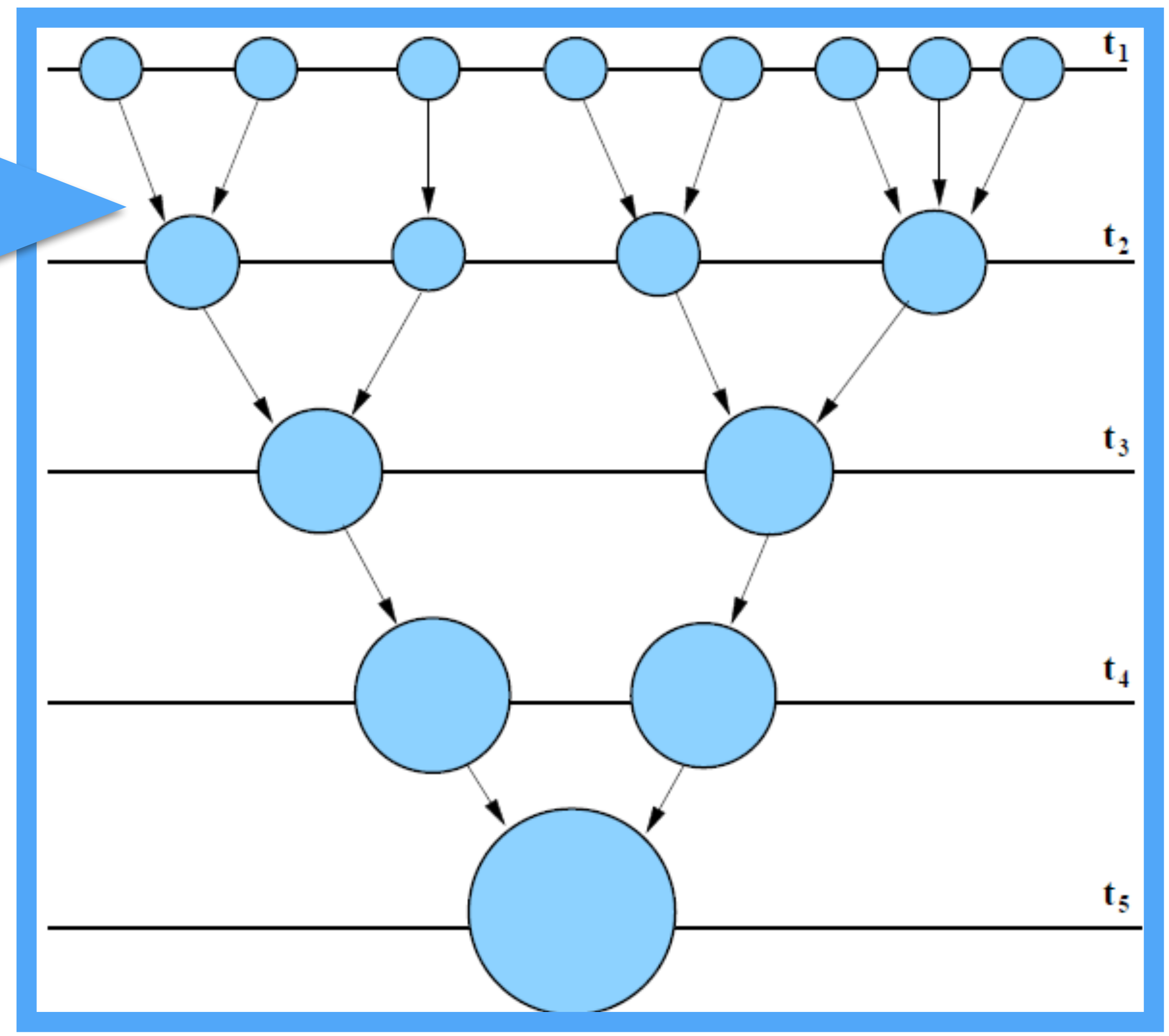


Semi Analytic Model (SAM) of galaxy formation

Enables a statistical study about the role of different AGN triggering mechanisms!

(Menci+2004,2006,2008,2014)



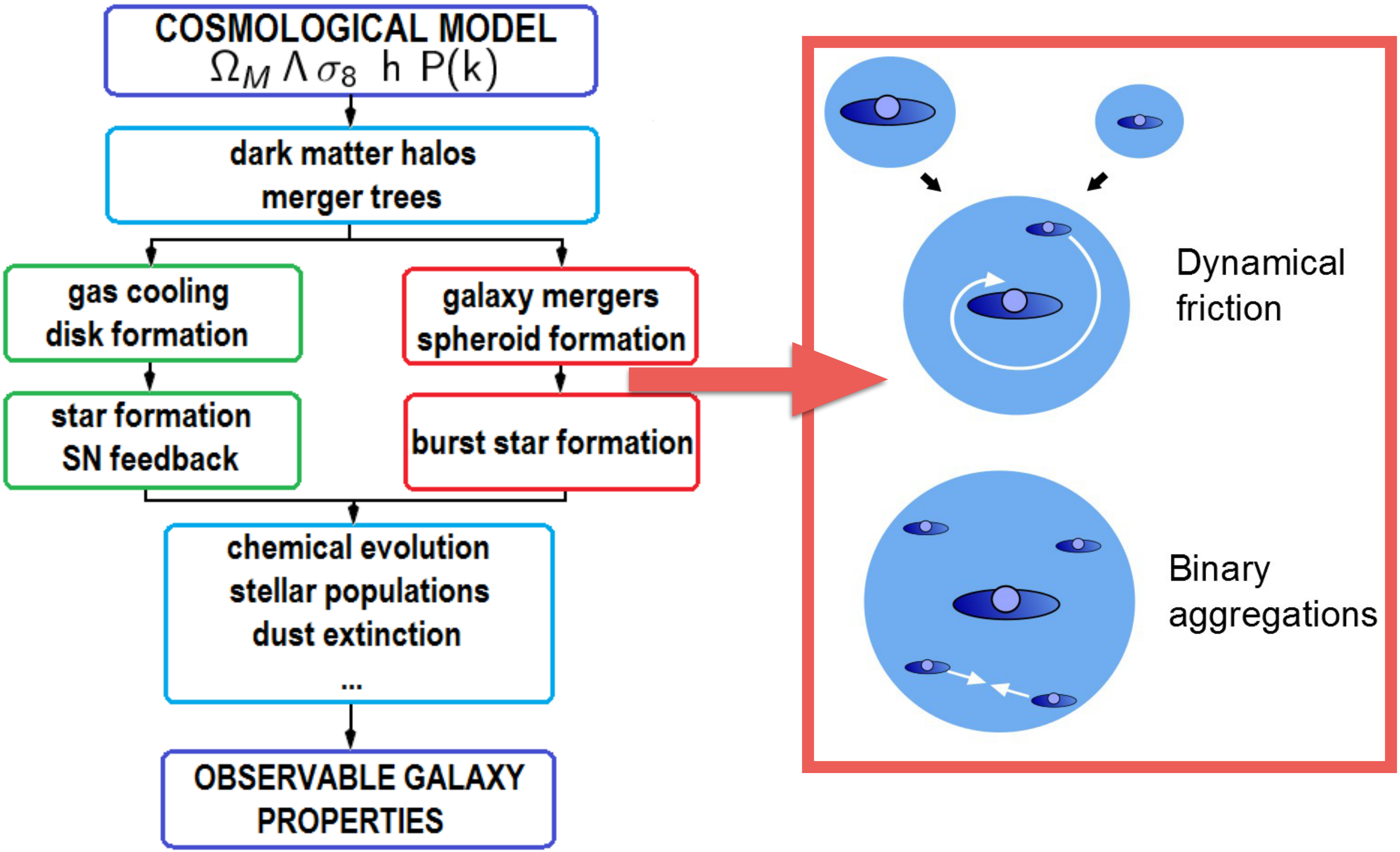


Monte Carlo realizations
EPS (Lacey & Cole 1993)

Semi Analytic Model (SAM) of galaxy formation

Enables a statistical study about the role of different AGN triggering mechanisms!

(Menci+2004,2006,2008,2014)



SAM: AGN triggering and BH accretion rate

GALAXY INTERACTIONS

DISK INSTABILITIES

SAM: AGN triggering and BH accretion rate

GALAXY INTERACTIONS

DISK INSTABILITIES

Trigger: galaxy interactions occur at a rate

$$\tau_r^{-1} = n \, \Sigma \, v_{rel}$$

SAM: AGN triggering and BH accretion rate

GALAXY INTERACTIONS

DISK INSTABILITIES

Trigger: galaxy interactions occur at a rate

$$\tau_r^{-1} = n \Sigma \ v_{rel}$$

BH accretion rate:
(Cavaliere & Vittorini 2000)

$$\dot{M}_{BH} \propto \frac{f \ M_{gas}}{\tau_b}$$

SAM: AGN triggering and BH accretion rate

GALAXY INTERACTIONS

Trigger: galaxy interactions occur at a rate

$$\tau_r^{-1} = n \Sigma \, v_{rel}$$

DISK INSTABILITIES

Trigger: galaxy disk mass (Efstathiou 1982)

$$M_{disk} > M_{crit}$$

BH accretion rate:
(Cavaliere & Vittorini 2000)

$$\dot{M}_{BH} \propto \frac{f \, M_{gas}}{\tau_b}$$

SAM: AGN triggering and BH accretion rate

GALAXY INTERACTIONS

Trigger: galaxy interactions occur at a rate

$$\tau_r^{-1} = n \Sigma v_{rel}$$

BH accretion rate:
(Cavaliere & Vittorini 2000)

$$\dot{M}_{BH} \propto \frac{f\ M_{gas}}{\tau_b}$$

DISK INSTABILITIES

Trigger: galaxy disk mass (Efstathiou 1982)

$$M_{disk} > M_{crit}$$

BH accretion rate:
(Hopkins & Quataert 2011)

$$\dot{M}_{BH} \propto \frac{f_d^{8/3} M_{disk}}{1+ f_0/f_{gas}}$$

How can we test our models?

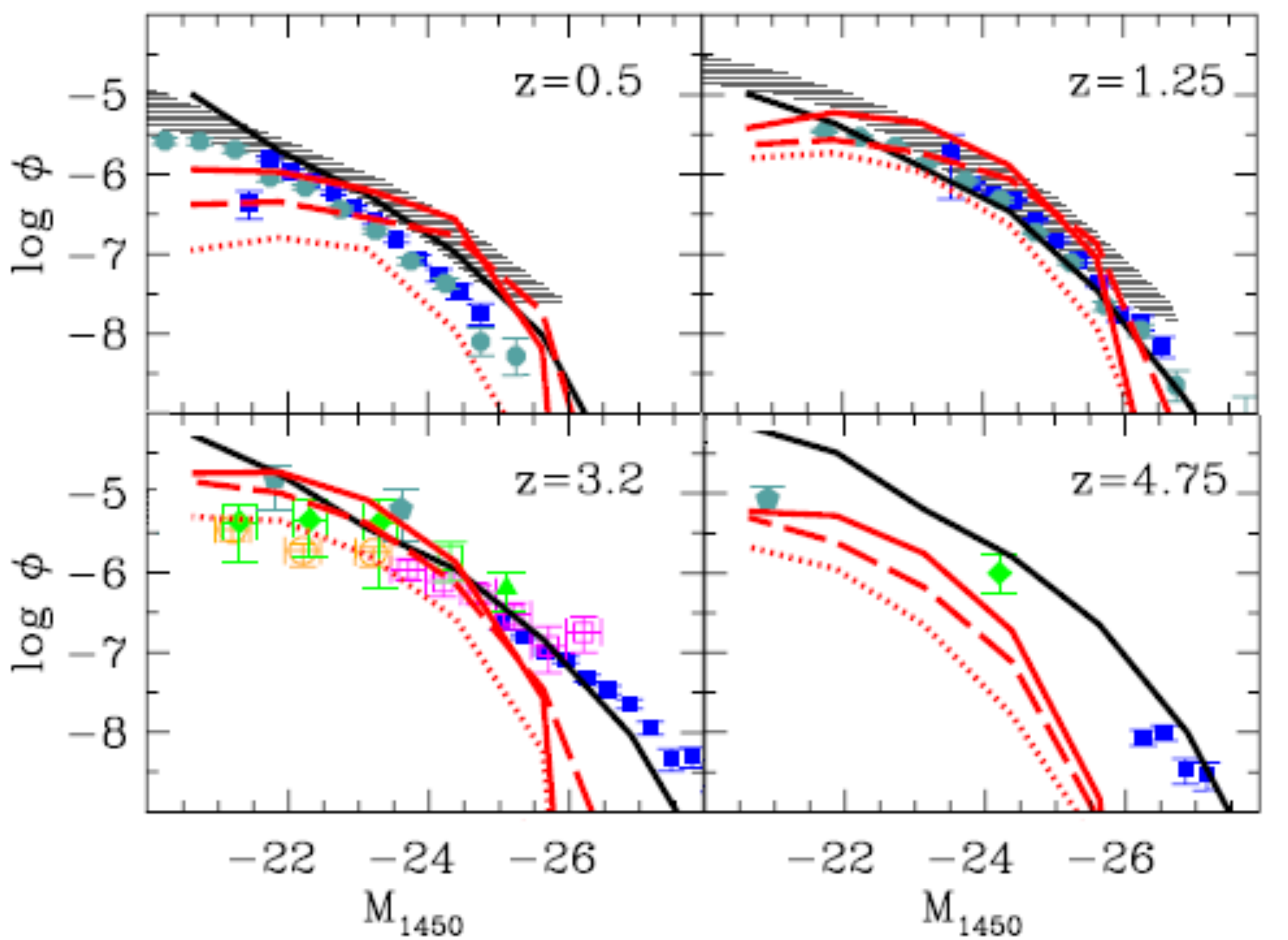
Comparing with different observational probes!

AGN and SMBH populations properties → which fraction of the AGN and SMBH populations is explained by our models?

AGN host galaxy properties → are we triggering AGN activity in realistic galaxies?

AGN clustering → which are the typical environments where AGN live?

AGN UV luminosity function



Model predictions:

Interactions

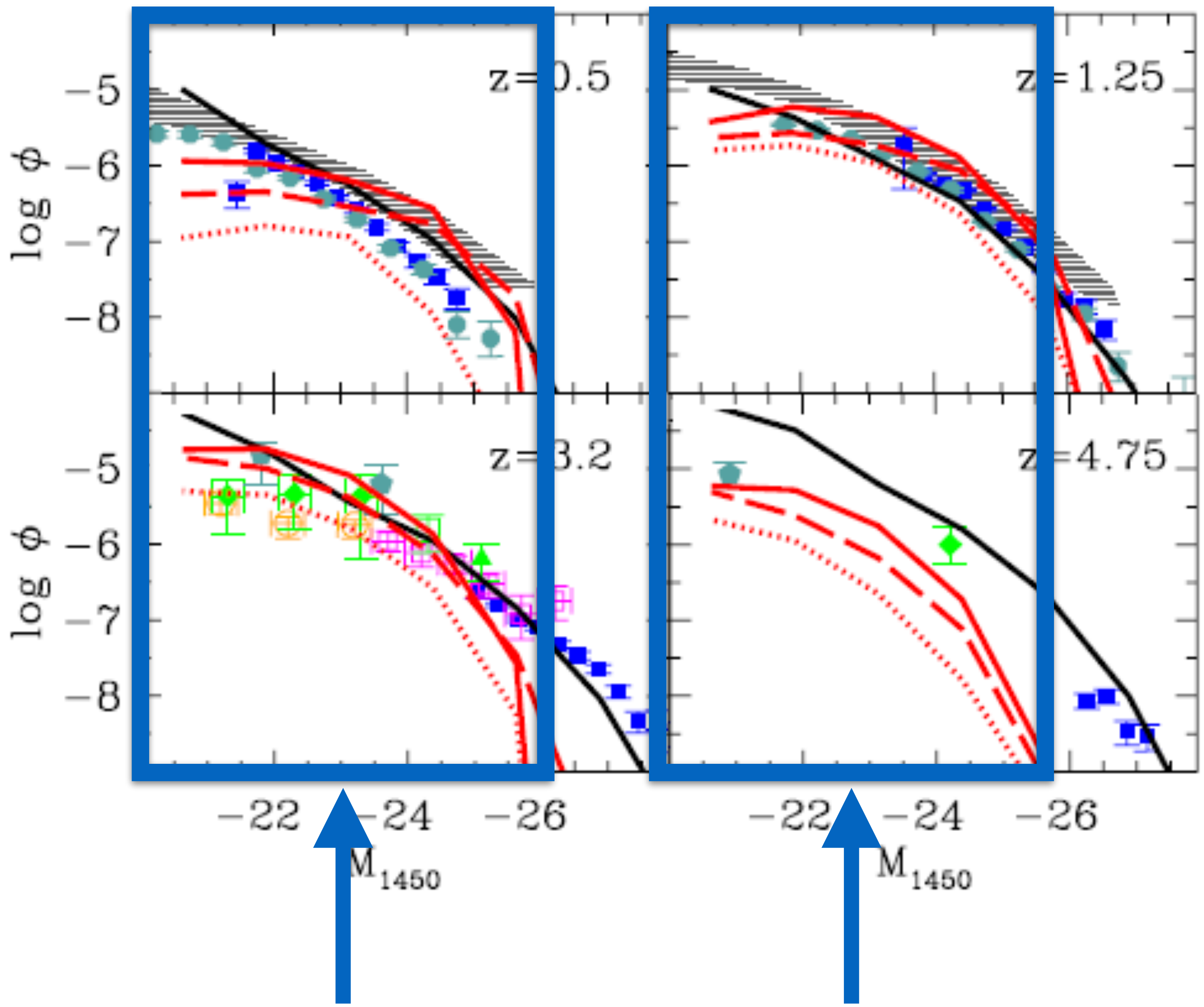
Disk instabilities: fiducial model

Disk instabilities (variation 1): exponential disk

Disk instabilities (variation 2): enhanced star formation

Data: Aird+10,Bongiorno+07,Brusa+10,Civano+11,Croom+09,Ebrero+09, Fiore+12,Fontanot+07,Jiang+09, La Franca+05,Glikman+11, Richards+06,Siana+08

AGN UV luminosity function



Model predictions:

Interactions

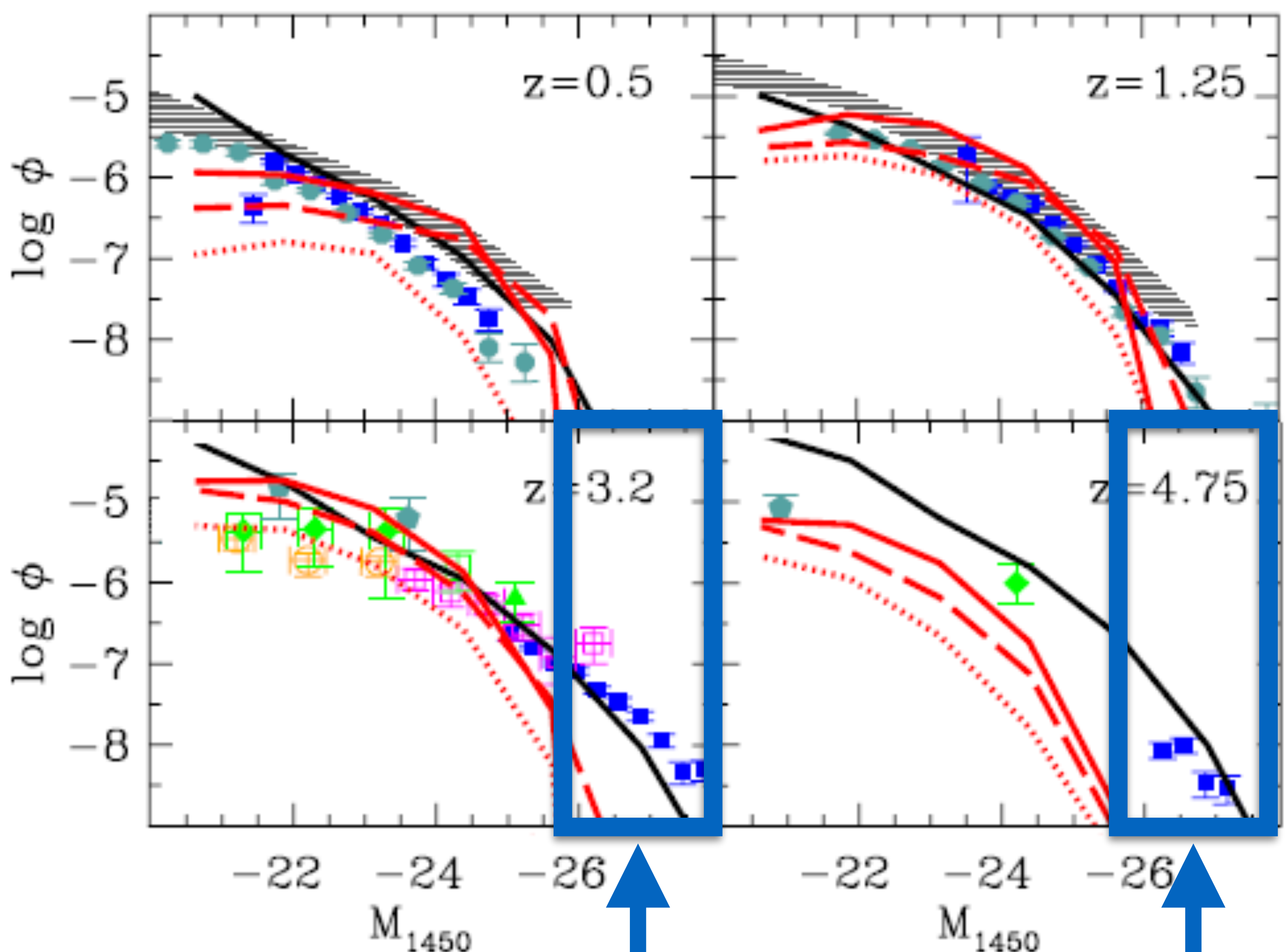
Disk instabilities: fiducial model

Disk instabilities (variation 1): exponential disk

Disk instabilities (variation 2): enhanced star formation

For moderately luminous AGN, **both disk instabilities and interactions can match** the observed AGN luminosity function

AGN UV luminosity function



Model predictions:

Interactions

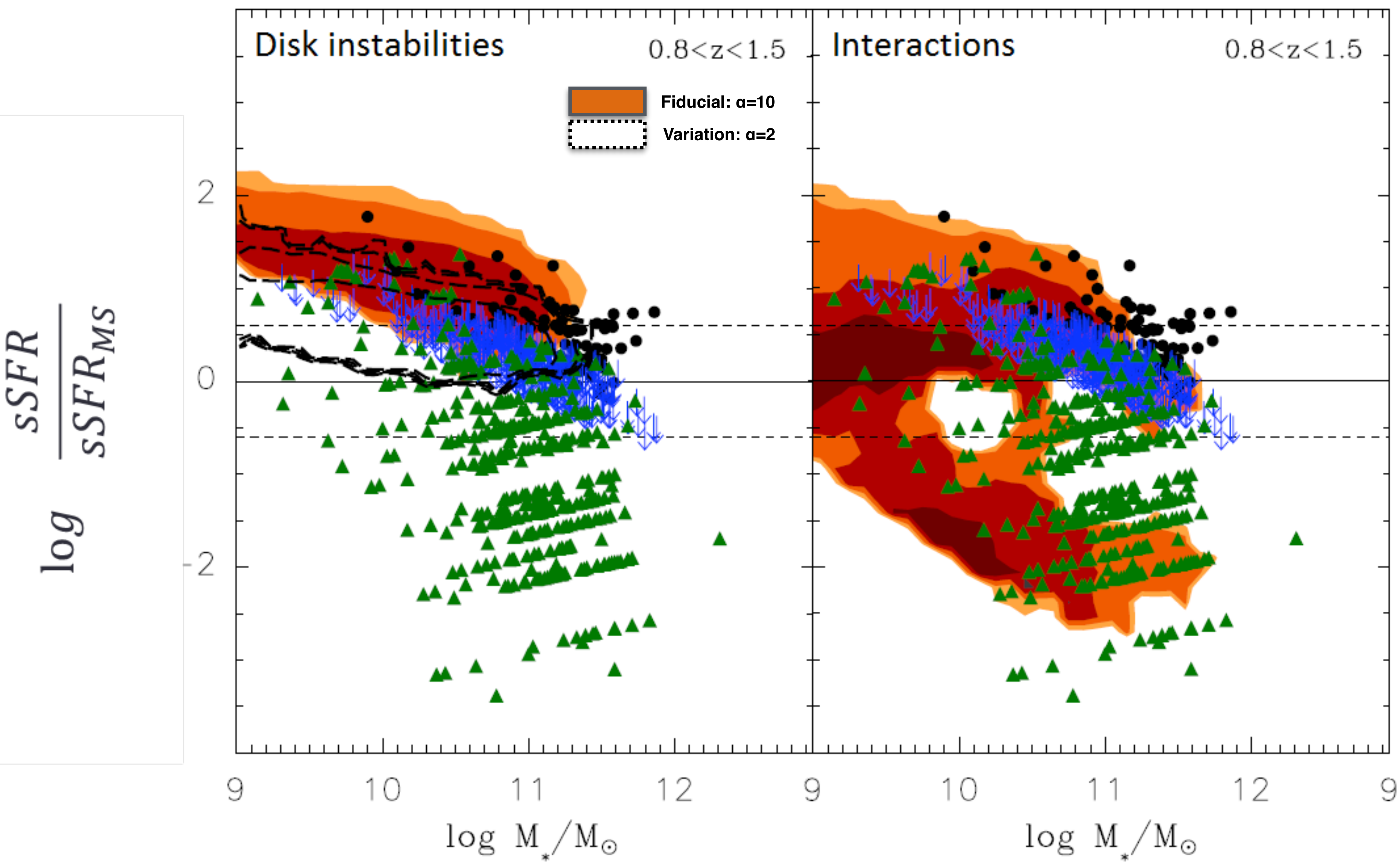
Disk instabilities: fiducial model

Disk instabilities (variation 1): exponential disk

Disk instabilities (variation 2): enhanced star formation

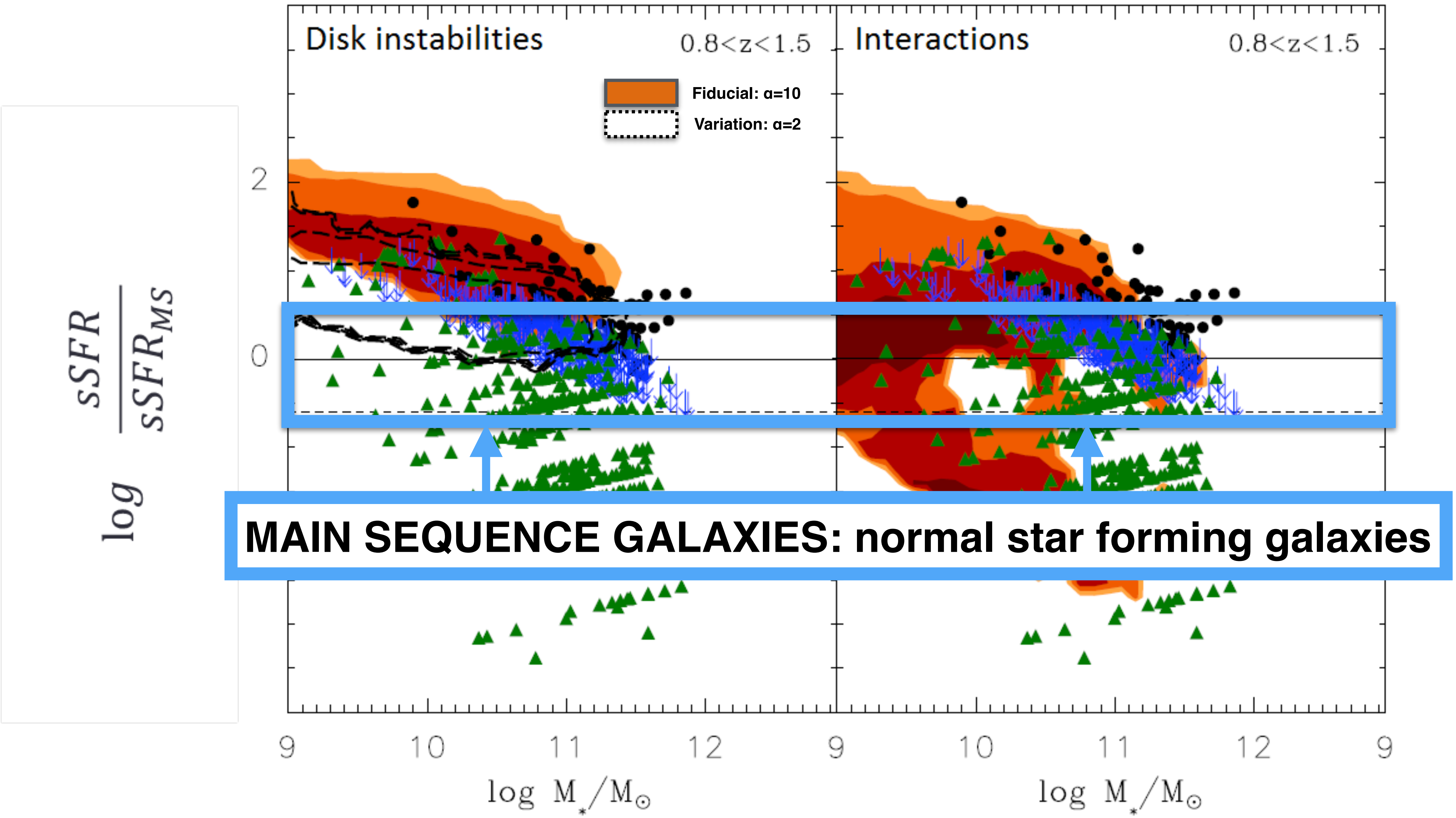
For **high luminosity, high z** AGN, the **disk instabilities scenario cannot match** the observed AGN luminosity function

AGN hosts star forming properties



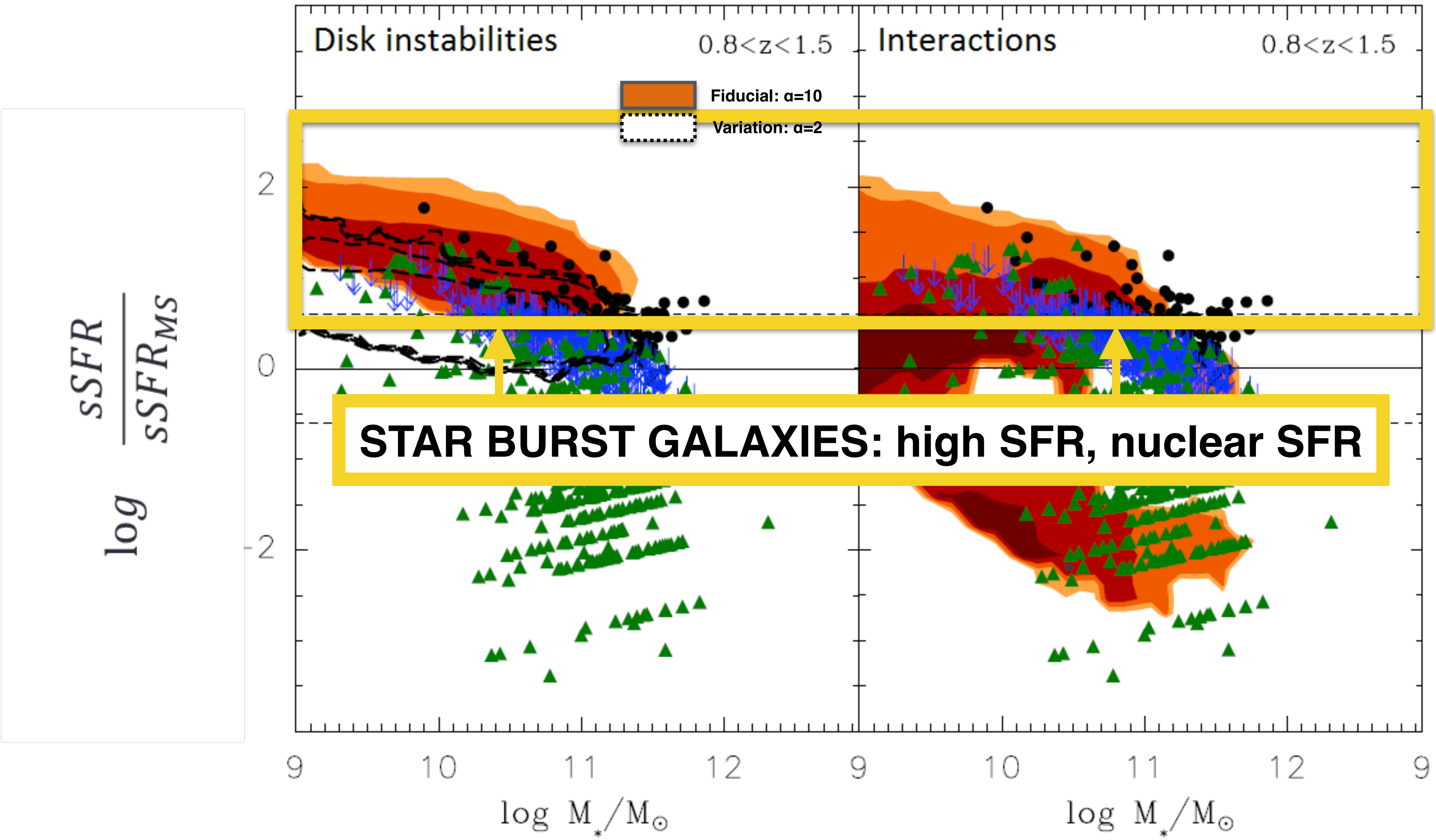
Data: Scoville+07, Cappelluti+09,Brusa+10, Santini+12,Bongiorno+12

AGN hosts star forming properties



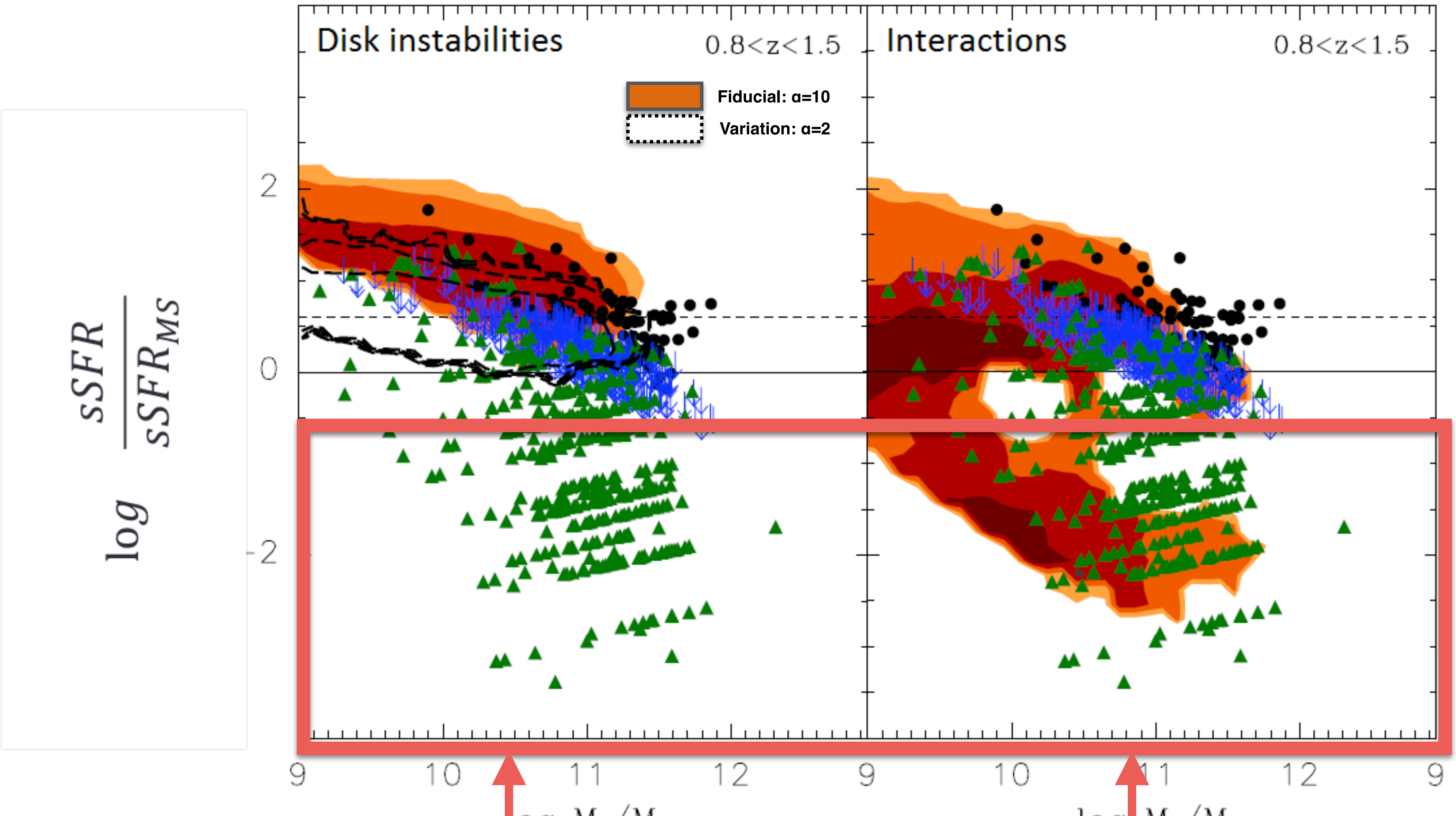
Data: Scoville+07, Cappelluti+09,Brusa+10, Santini+12,Bongiorno+12

AGN hosts star forming properties



Data: Scoville+07, Cappelluti+09,Brusa+10, Santini+12,Bongiorno+12

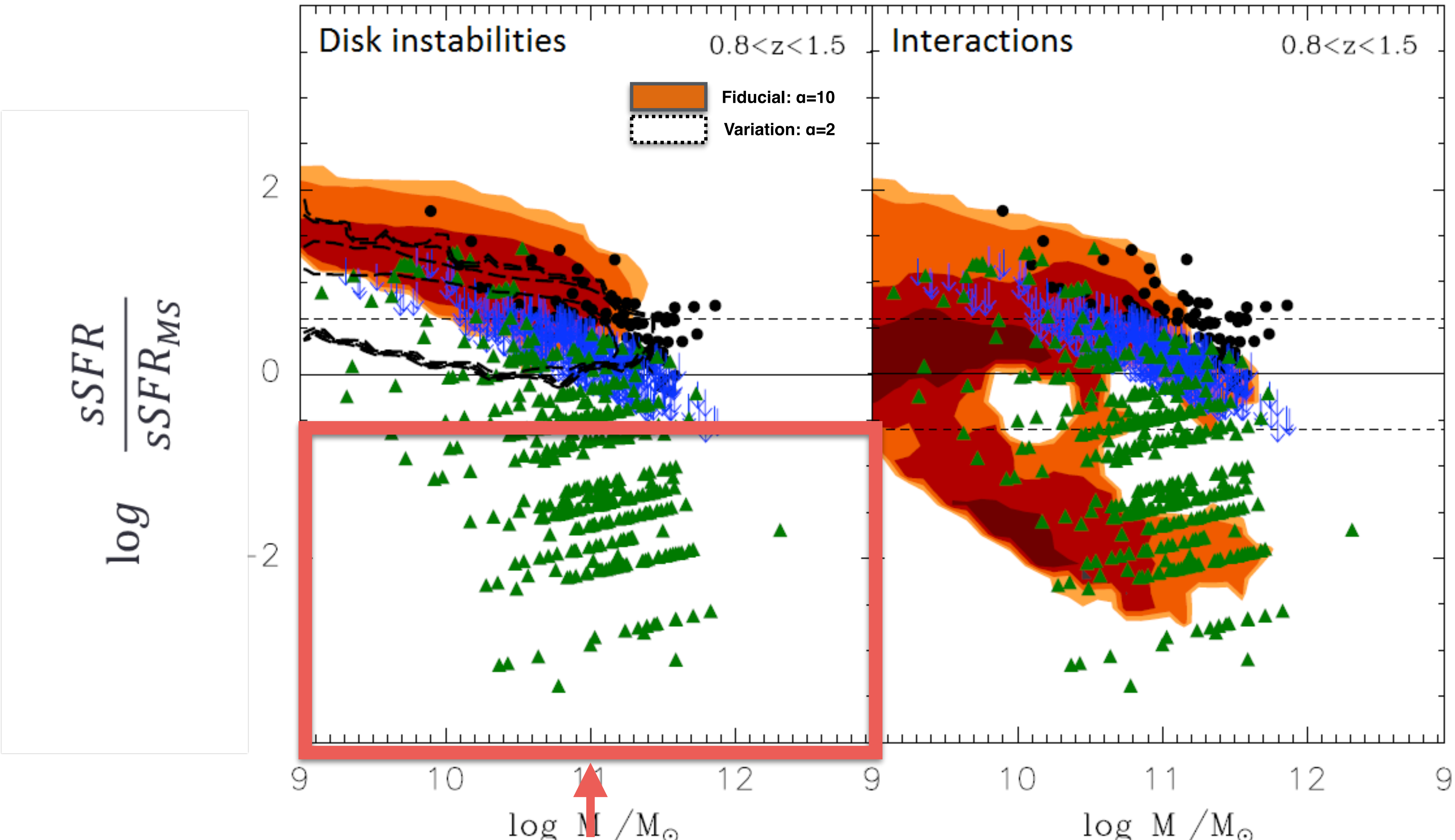
AGN hosts star forming properties



PASSIVE GALAXIES: quenched SFR

Data: Scoville+07, Cappelluti+09,Brusa+10, Santini+12,Bongiorno+12

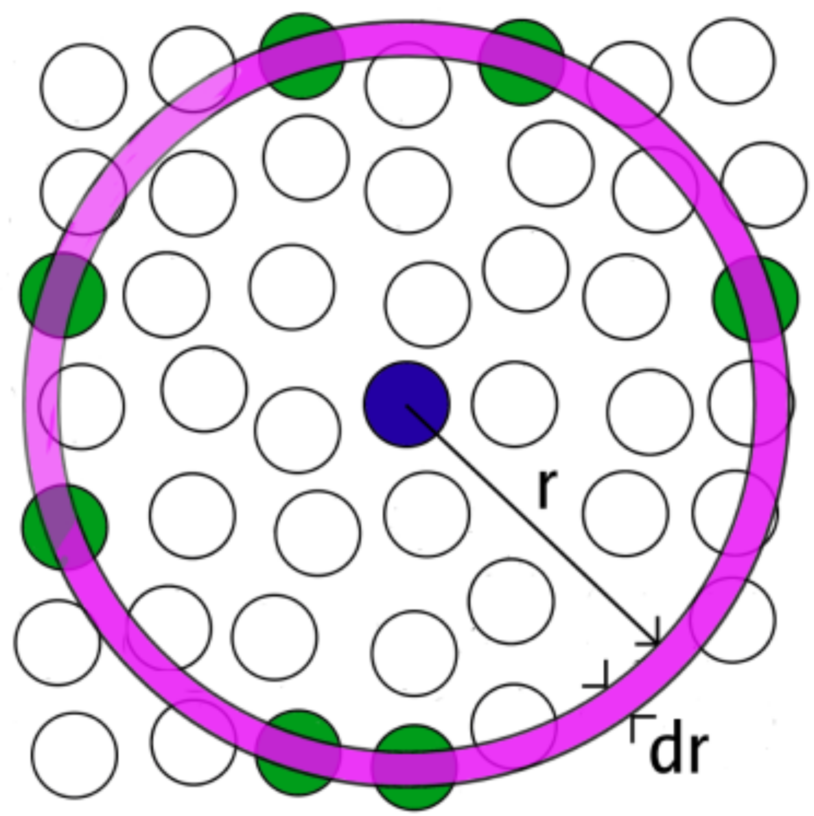
AGN hosts star forming properties



DISK INSTABILITIES are not able to trigger AGN activity in passive galaxies!

AGN clustering:
AGN auto-correlation function

auto-correlation function measures the probability
over random of finding pairs of objects at a given spatial separation

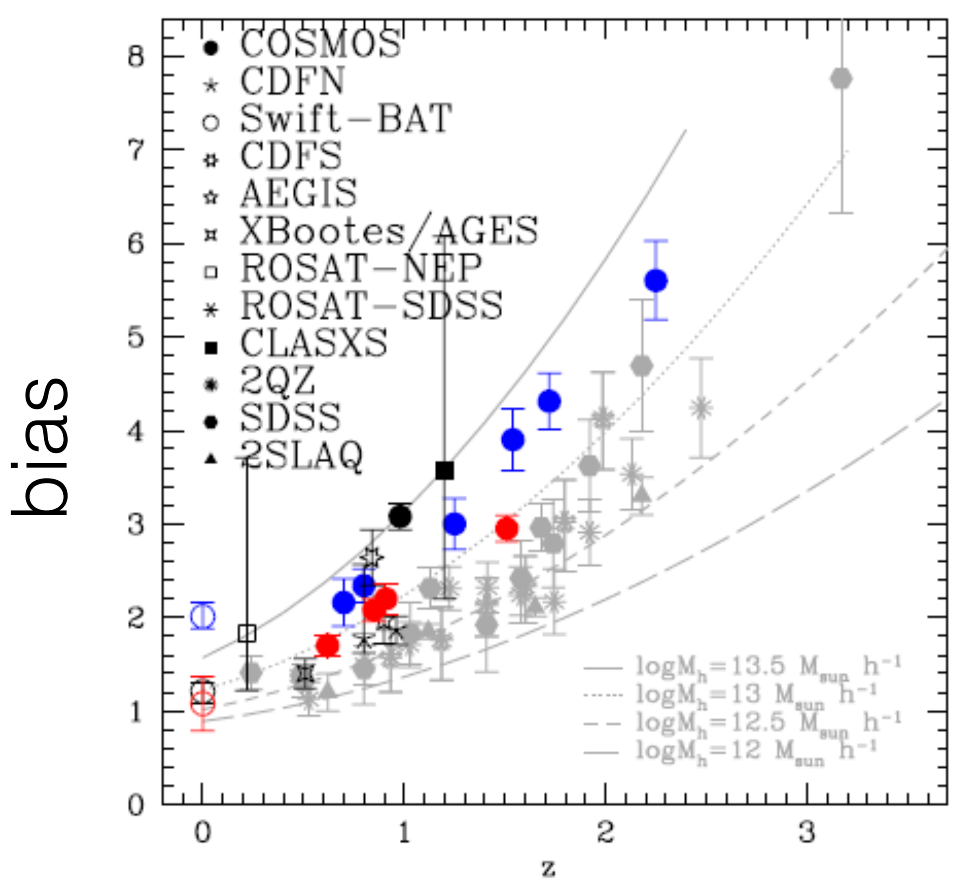


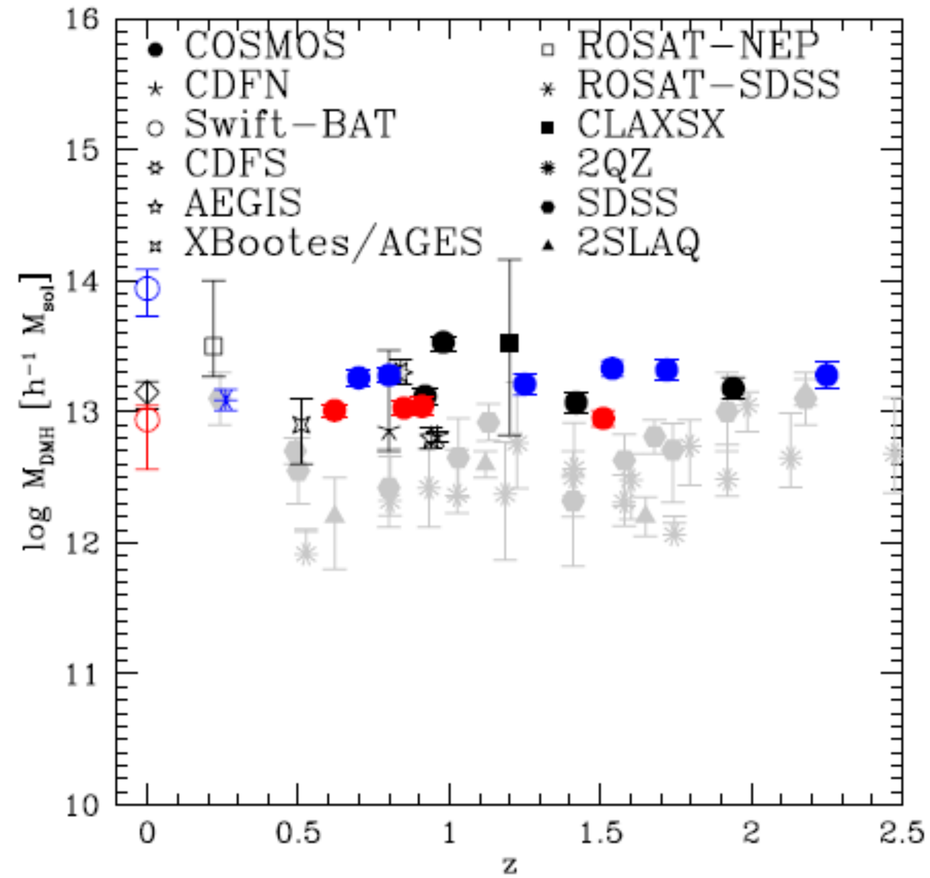
At large scales (linear regimes):

$$\omega_{AGN} \approx b^2_{AGN}\omega_{DM}$$

AGN clustering:
AGN auto-correlation function

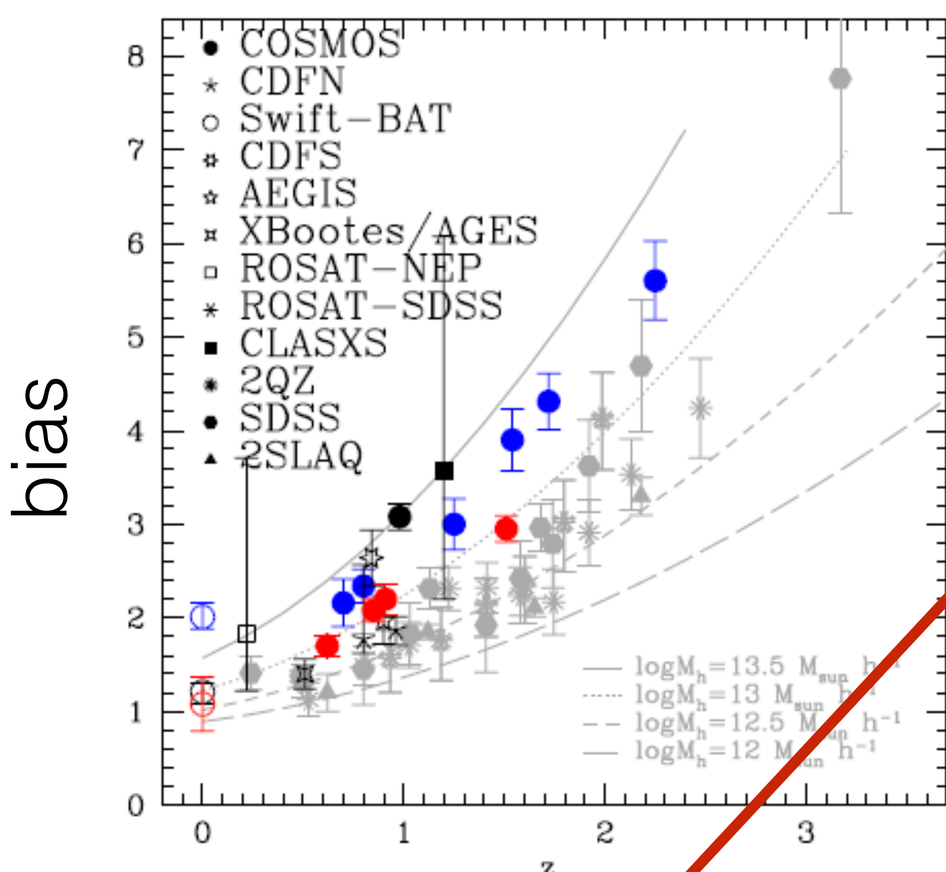
AGN bias factor → AGN “typical”halo mass

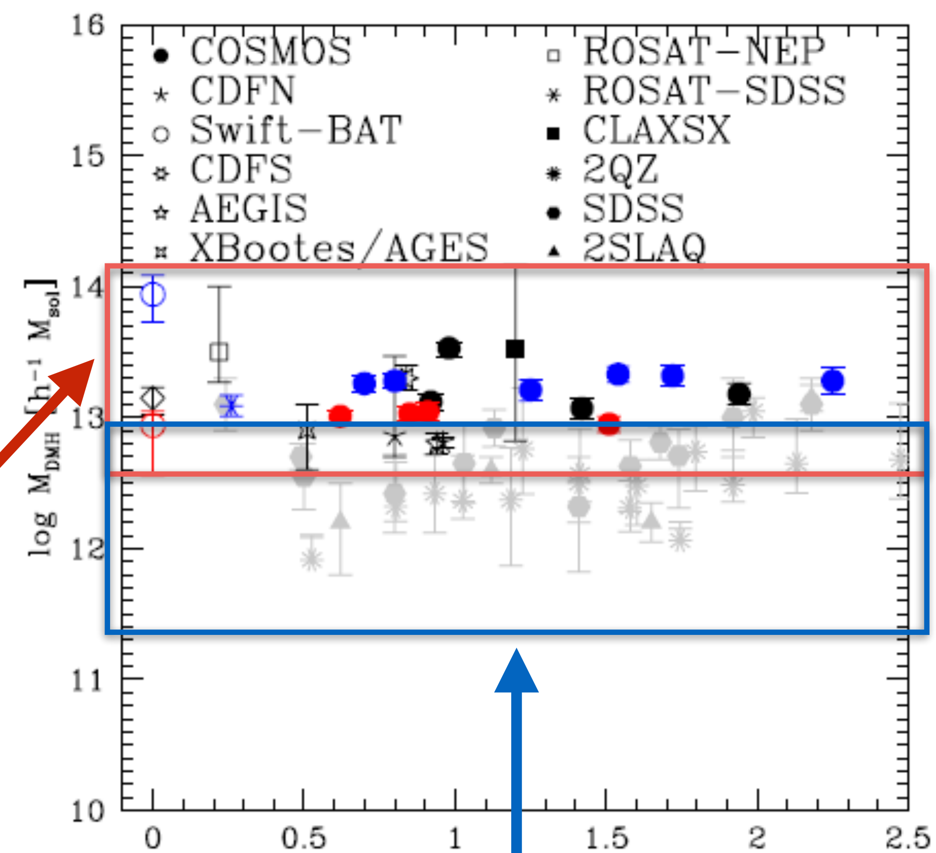




AGN clustering:
AGN auto-correlation function

AGN bias factor → AGN "typical"halo mass



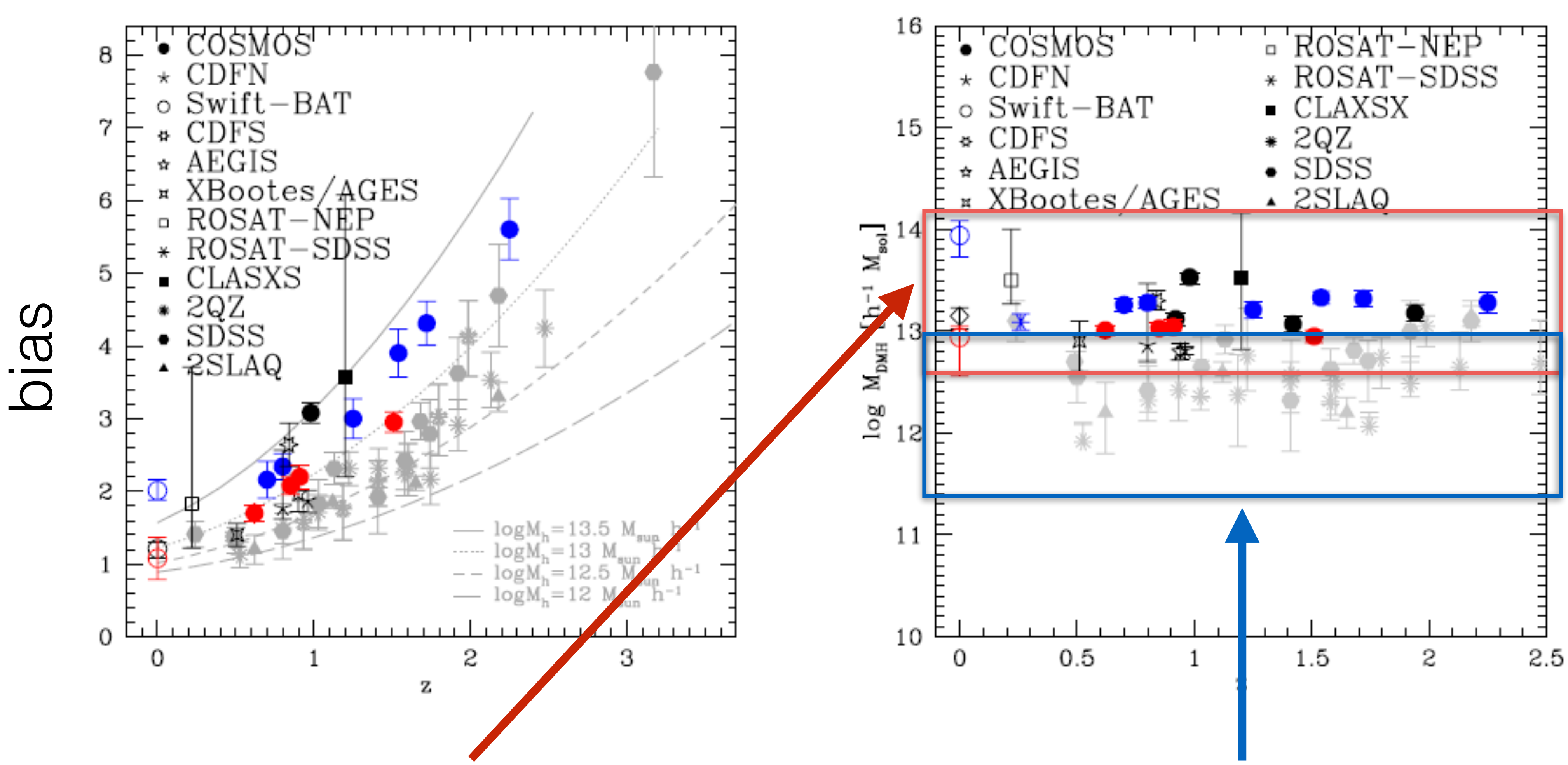


X-ray selected AGN

optically selected AGN

AGN clustering:
AGN auto-correlation function

AGN bias factor → AGN "typical"halo mass



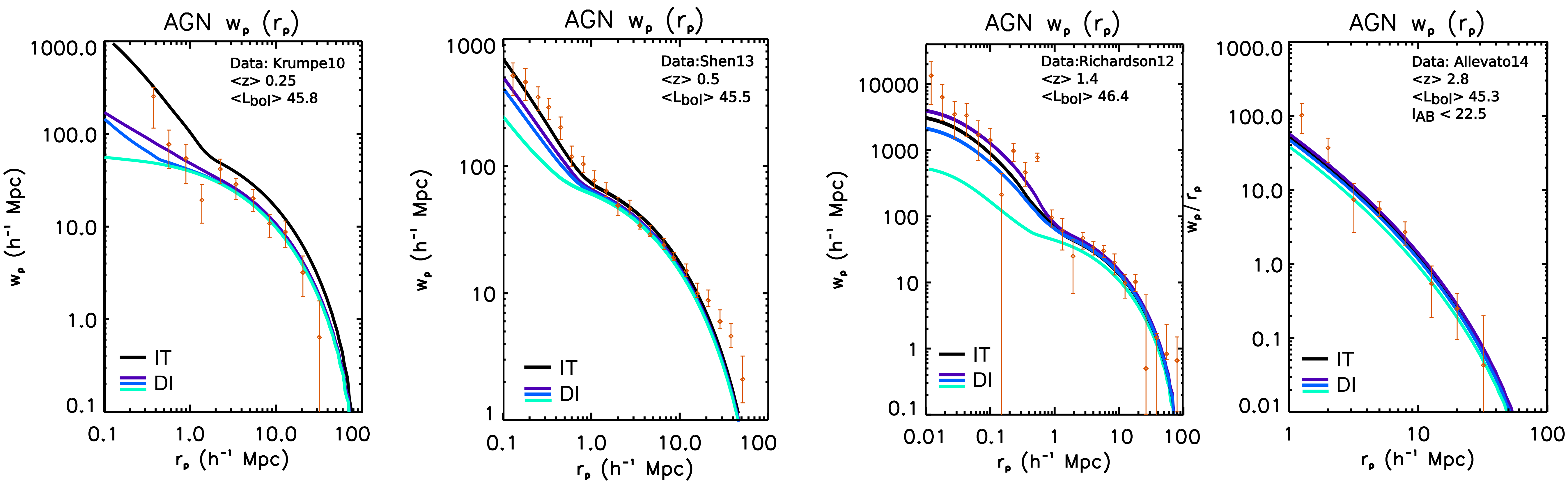
X-ray selected AGN

optically selected AGN

Possible hint of different triggering mechanisms at play?

AGN clustering:
AGN auto-correlation function

X-ray selected | **optically selected** | **optically selected** | **X-ray selected**



At scales > 1 Mpc/h, DI and IT yield similar clustering strength , compatible with bot X-ray and optical observations

Differences between X-ray and optical surveys mainly driven by different (often implicit) selection cuts

Conclusions

The inclusion of different feeding mechanisms into a semi-analytic model of galaxy formation is an effective way to investigate the triggering of AGN activity in galaxies

Conclusions

The inclusion of different feeding mechanisms into a semi-analytic model of galaxy formation is an effective way to investigate the triggering of AGN activity in galaxies

Galaxy interactions (mergers and fly-by event) are able to reproduce many observed properties of the AGN and host galaxy populations

Disk instabilities are able to provide the accretion rate needed to feed moderately luminous AGN, hosted in medium-sized, actively star forming galaxies

Further perspectives..

Buon appetito!