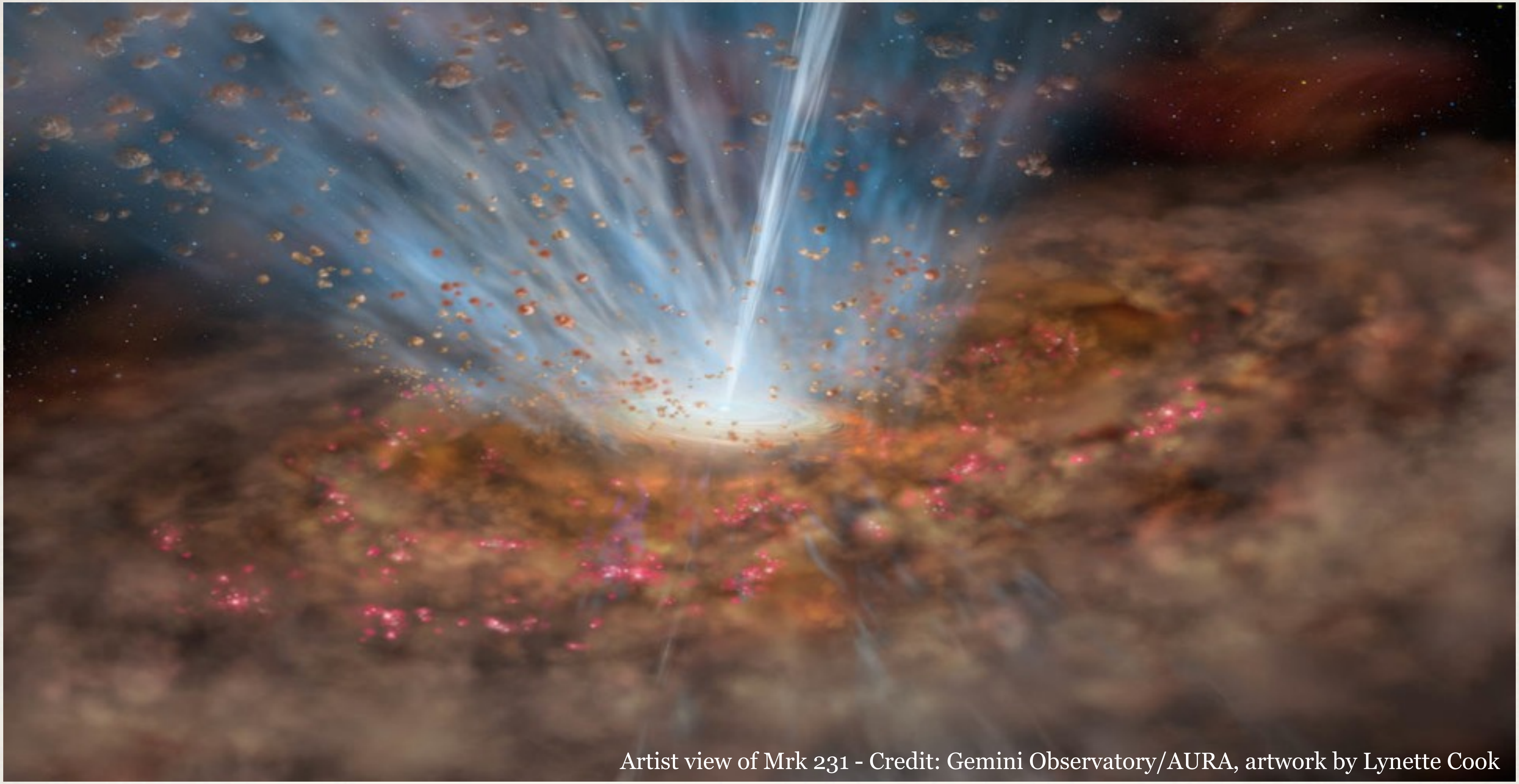


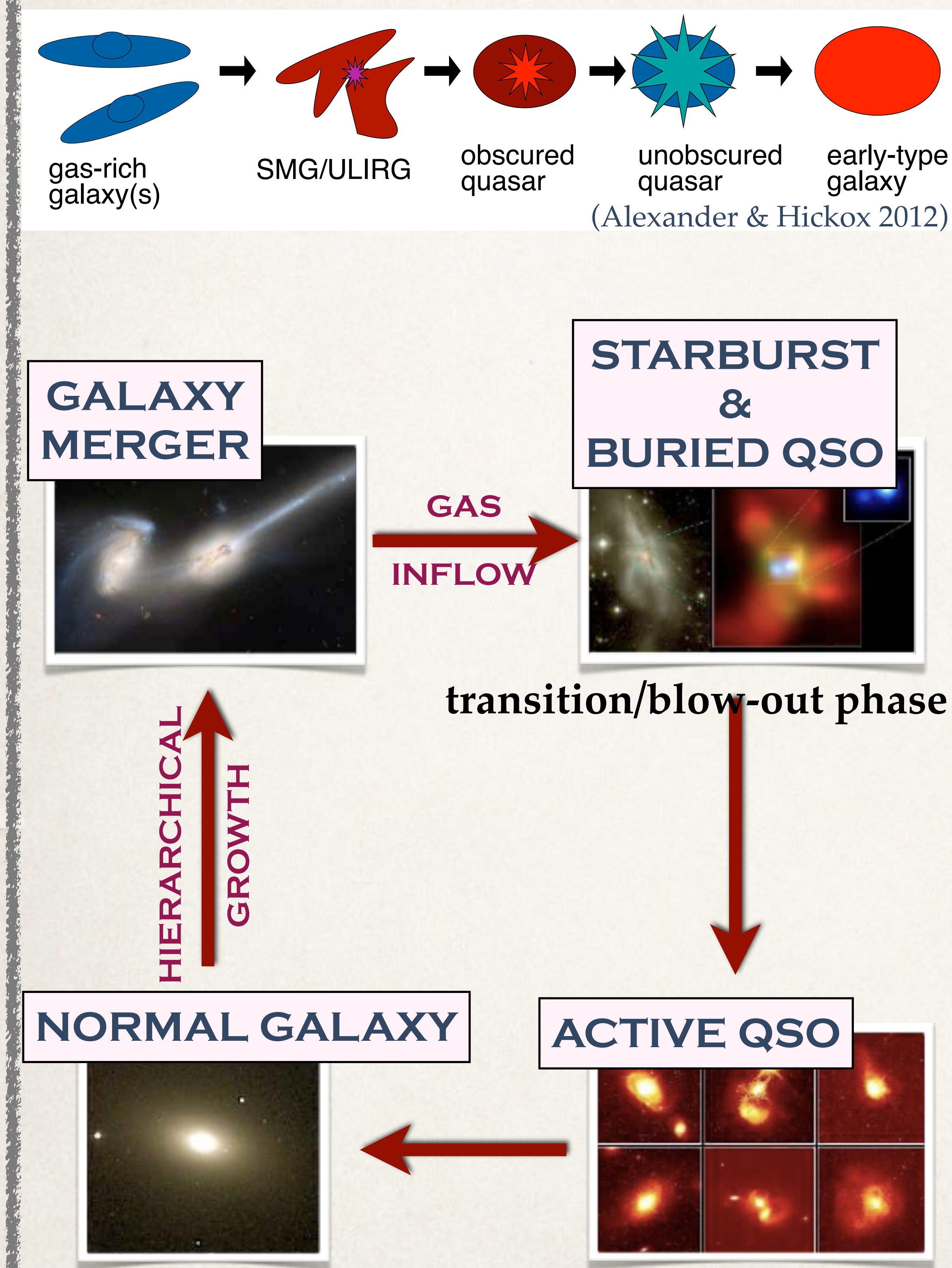
AGN host galaxy properties and mass function

Angela Bongiorno (INAF - OAR)

AGN12: A Multi-messenger Perspective - Napoli - 26-29 September 2016

AGN-galaxy coevolution model

AGN-GALAXY COEVOLUTION



(Hopkins+08)

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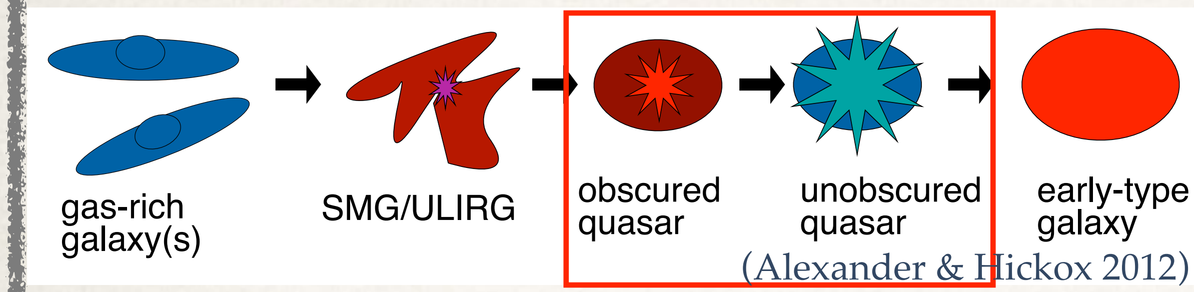
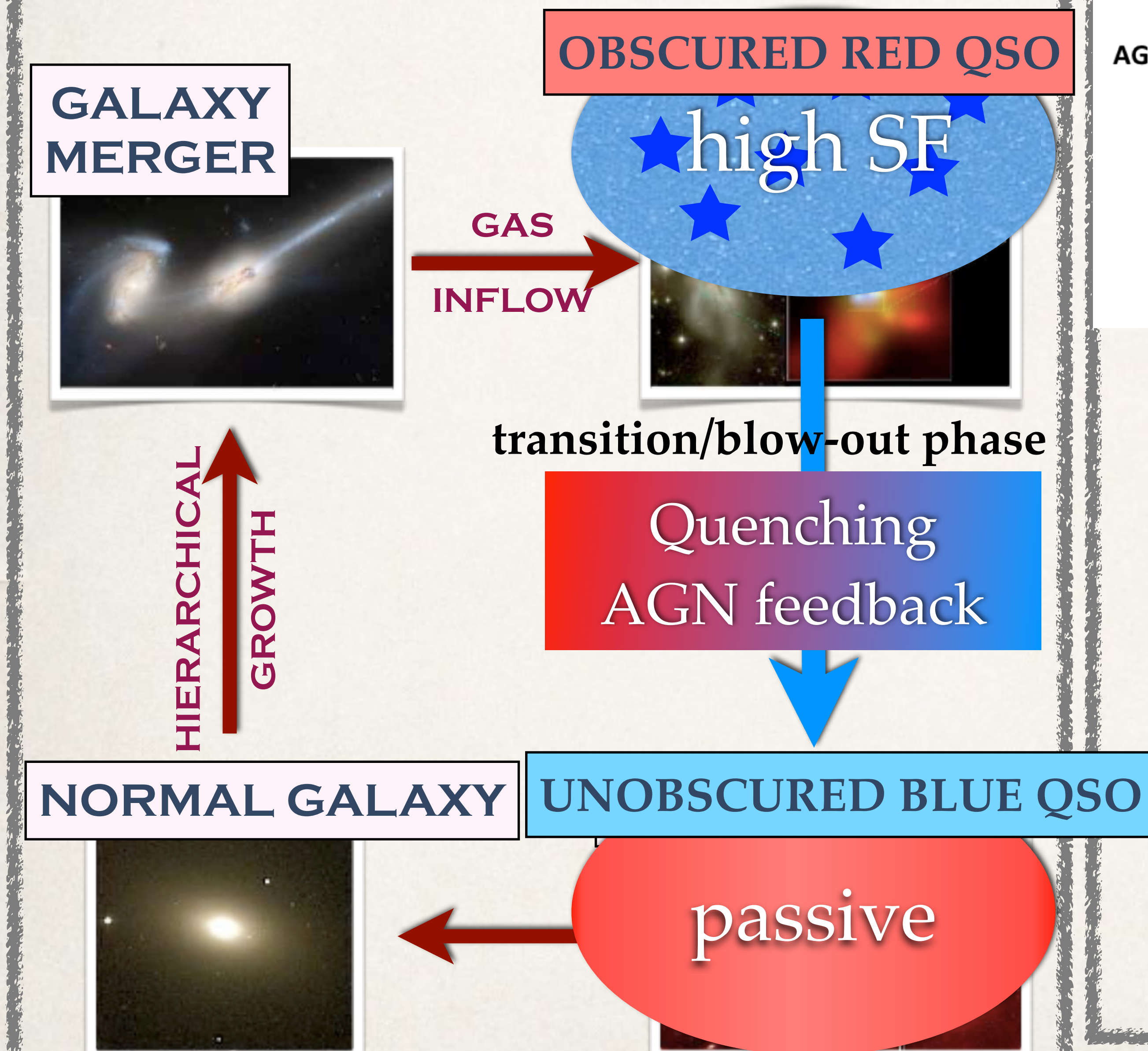
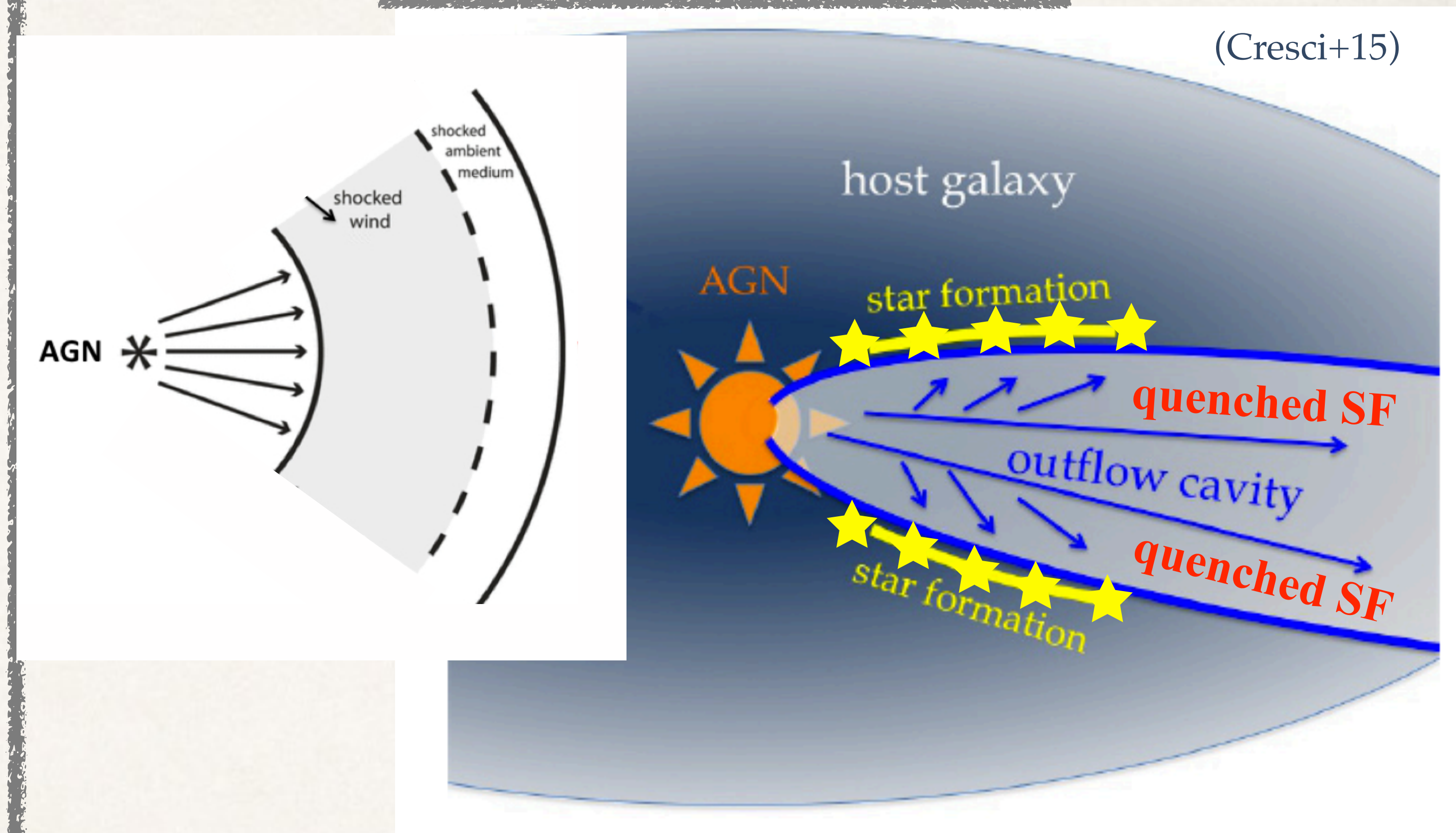




(Hopkins+08)

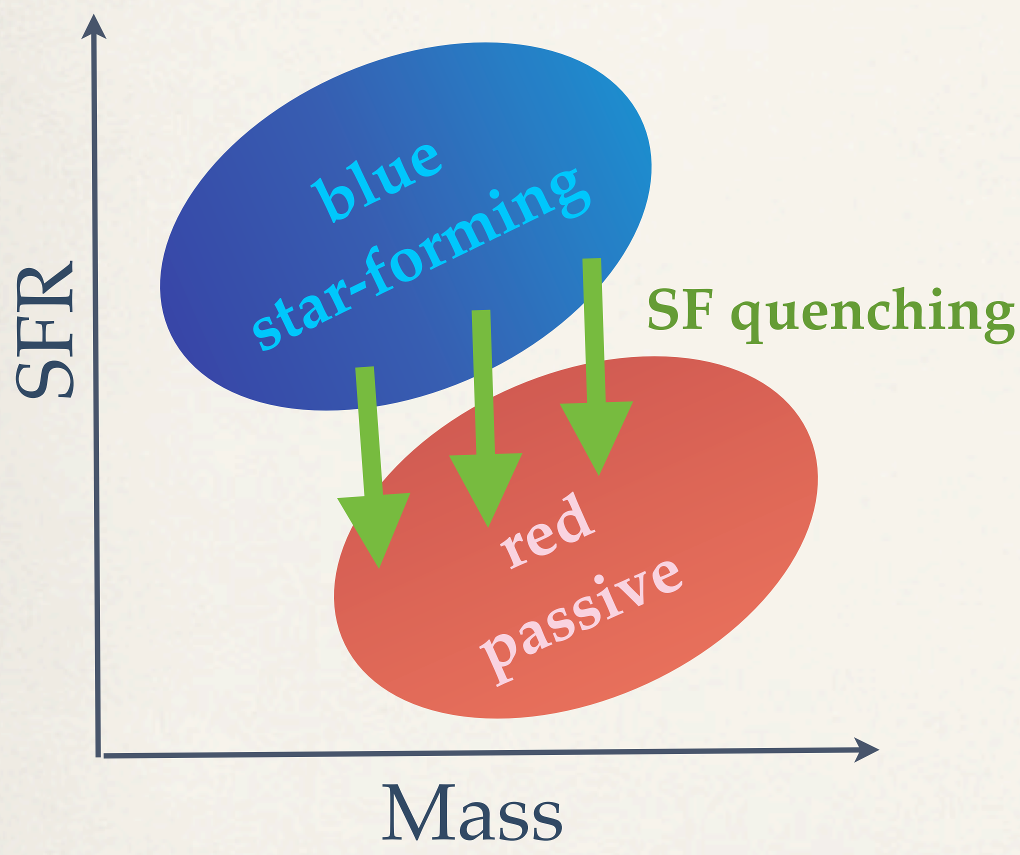
AGN-DRIVEN OUTFLOW



- **"Negative Feedback"**: the outflow may inhibit SF in the host by clearing/heating the interstellar gas (Zubovas & King 2012)
- **"Positive Feedback"**: the outflow might also be responsible for inducing SF in the host through gas compression at its edges (e.g. Silk 2013, King 2005; Imanishi & Fabian 2012)

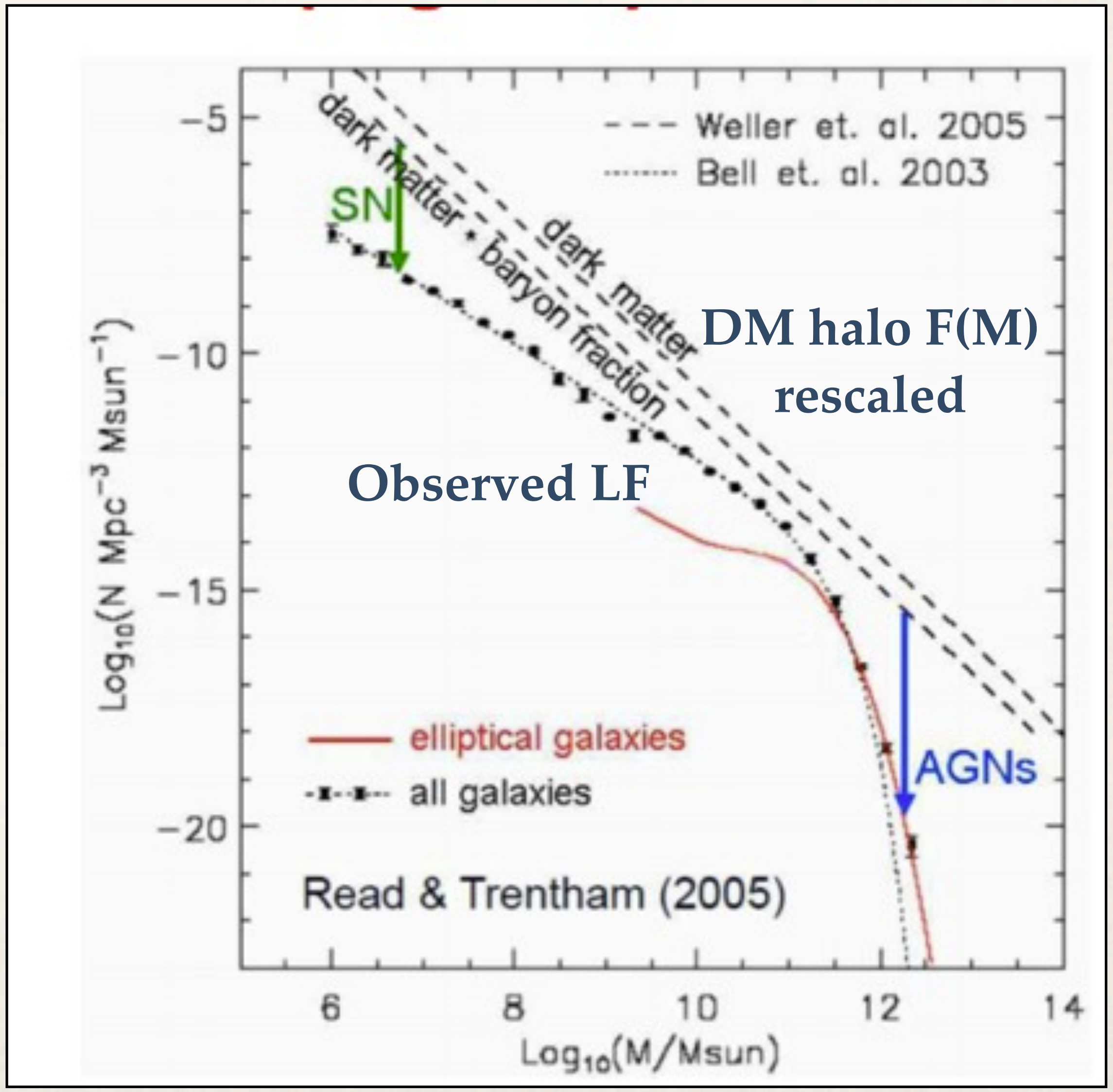
The need for negative feedback

(i) Explains red and dead properties of local ellipticals (SF QUENCHING)



(ii) Invoked for the M_{BH} - M_* relation

(iii) Prevents overgrowth of massive galaxies (where SN feedback is not enough)



Feedback: observational evidences

Direct feedback observations

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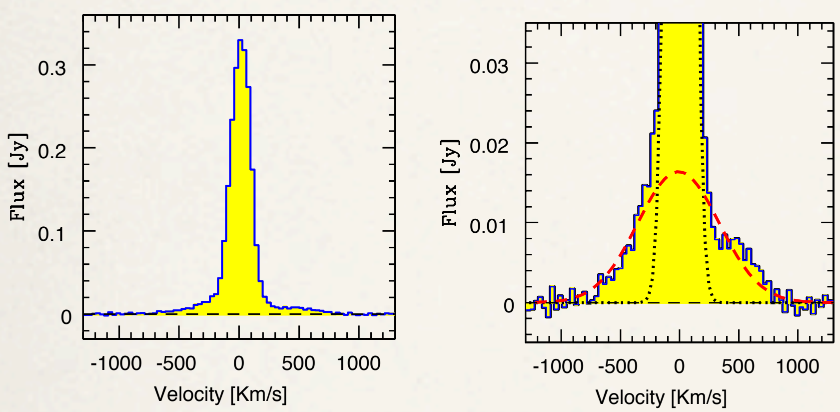
Direct feedback observations

Massive outflow of several **kpc** scales
(Cano-Diaz+12, Feruglio+10, Brusa+15,Feruglio+15)



Star formation strongly suppressed in the region
with the highest outflow velocity
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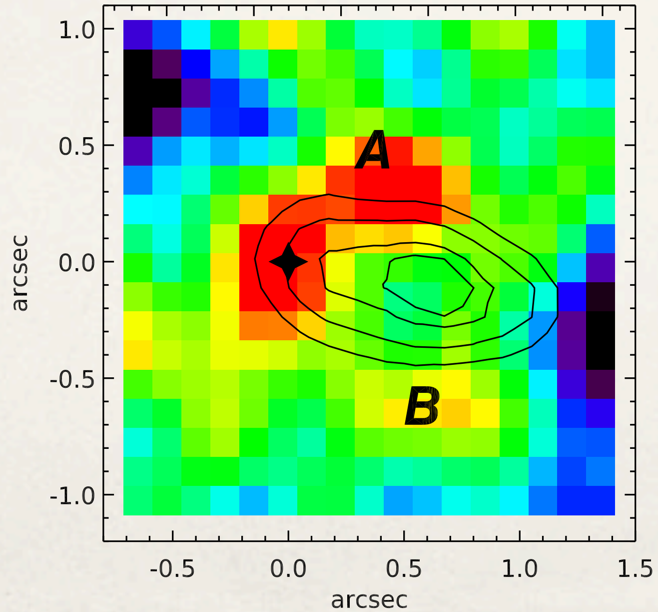

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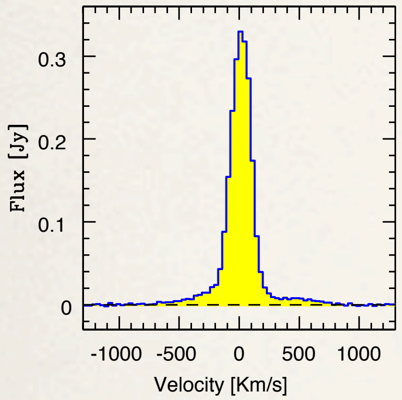

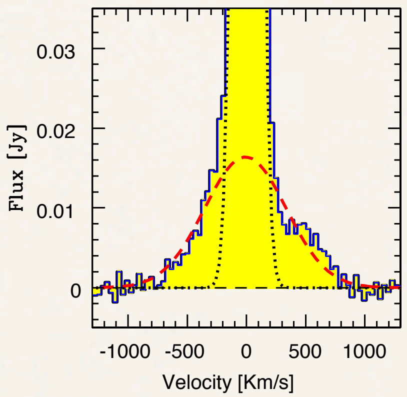

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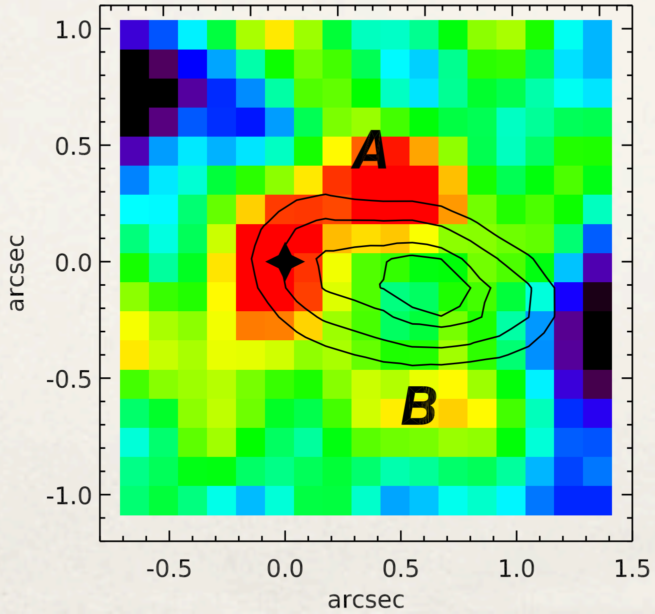

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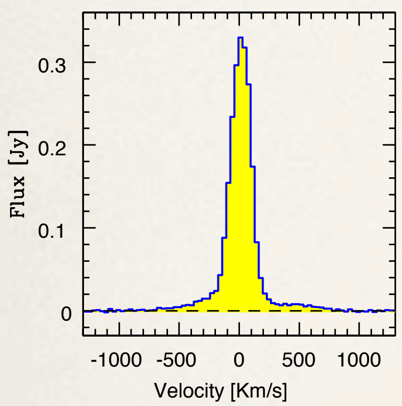

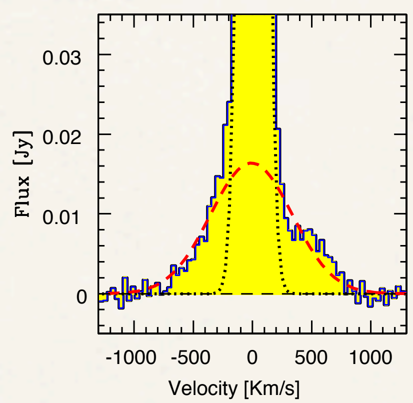

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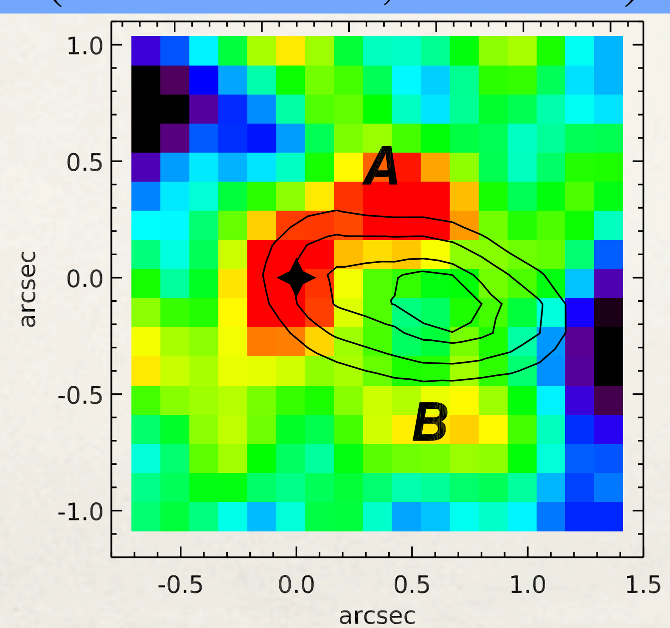

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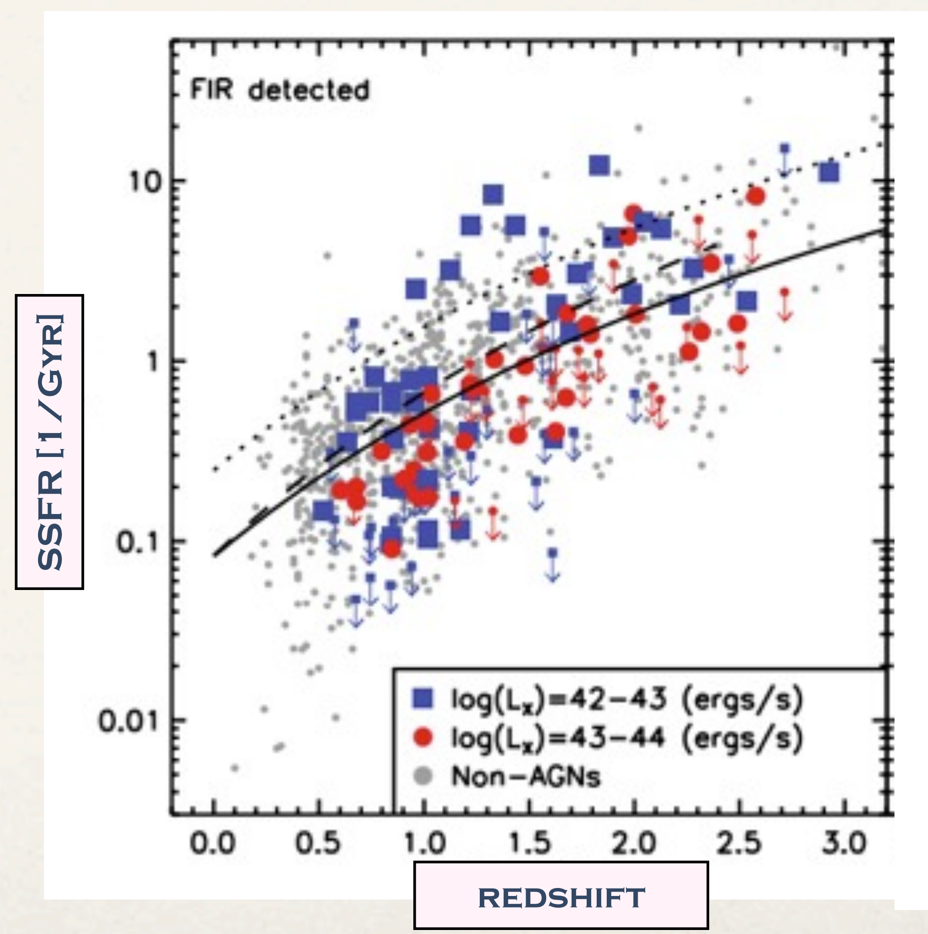

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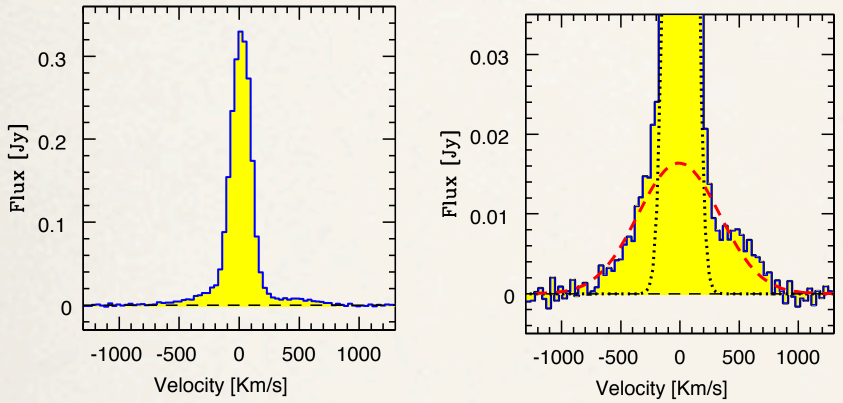

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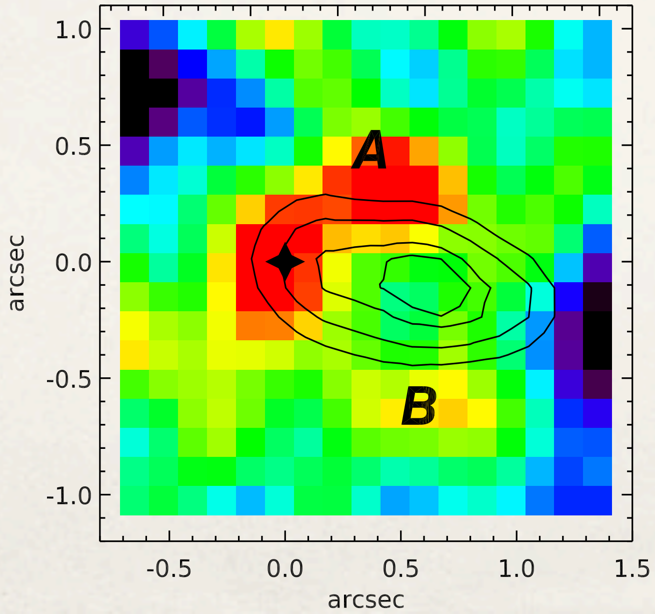

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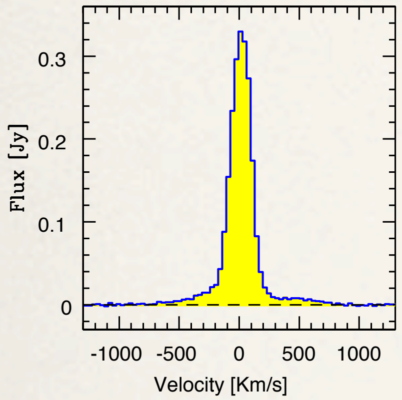

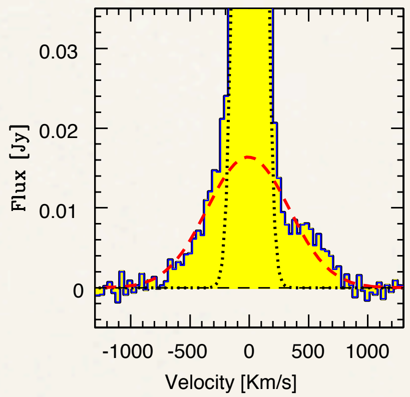

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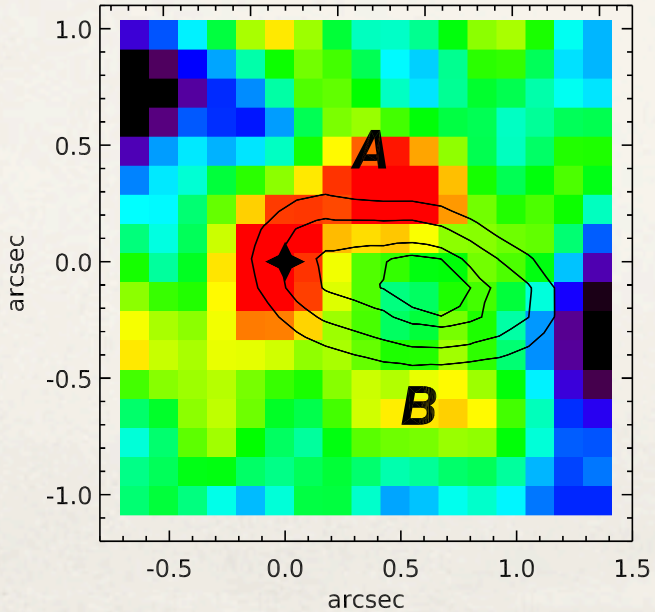

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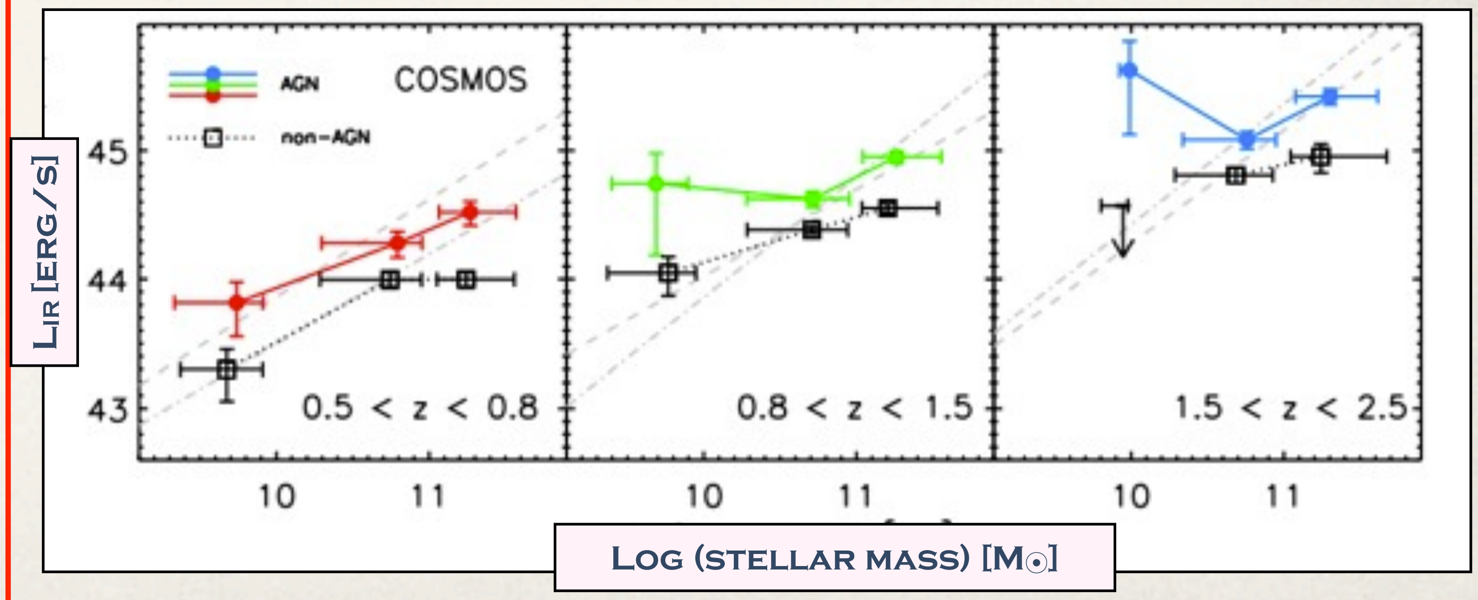

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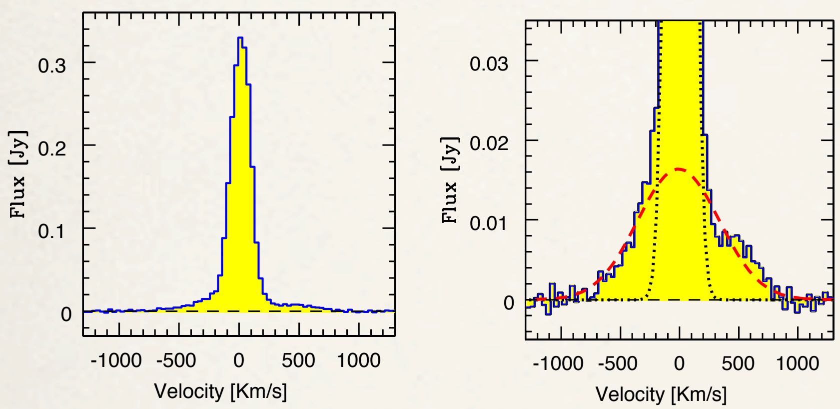

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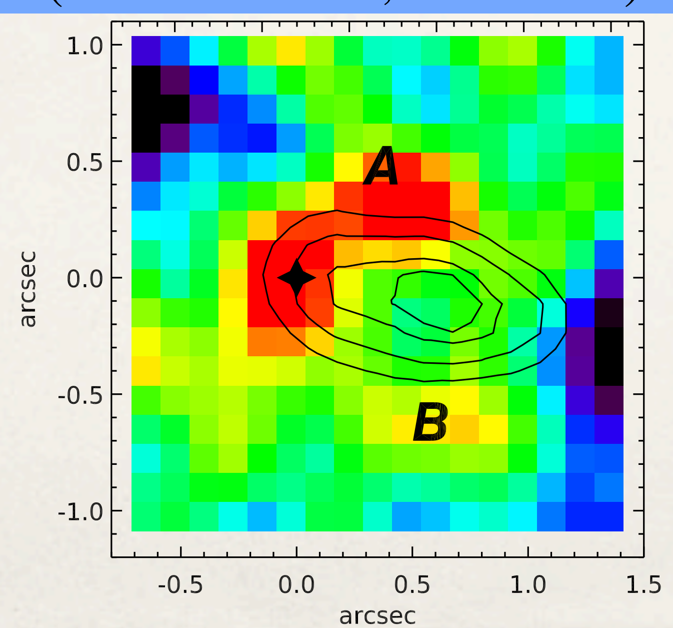

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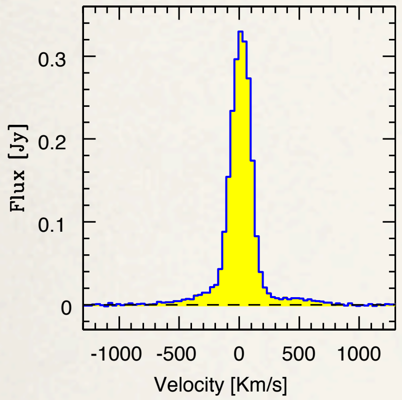

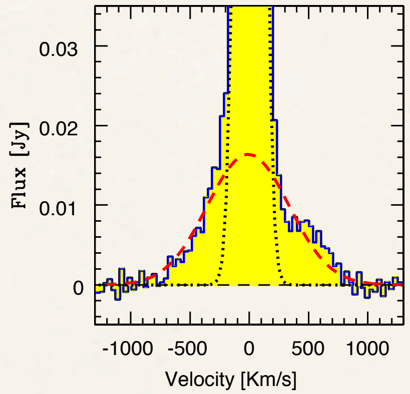

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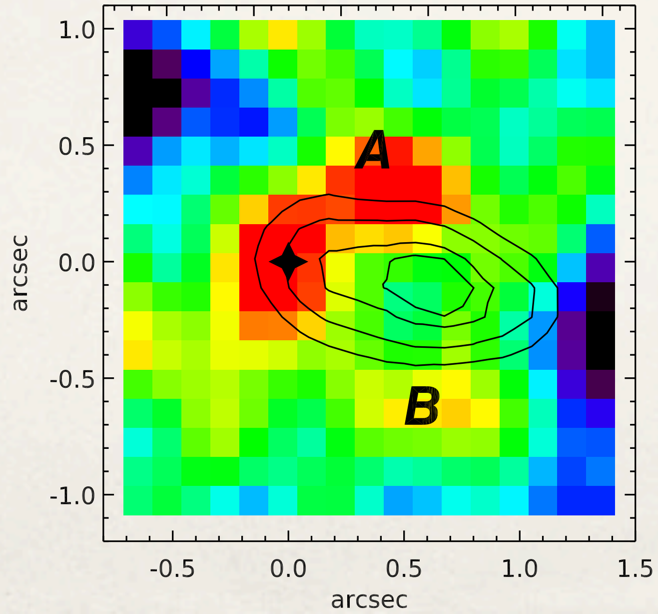

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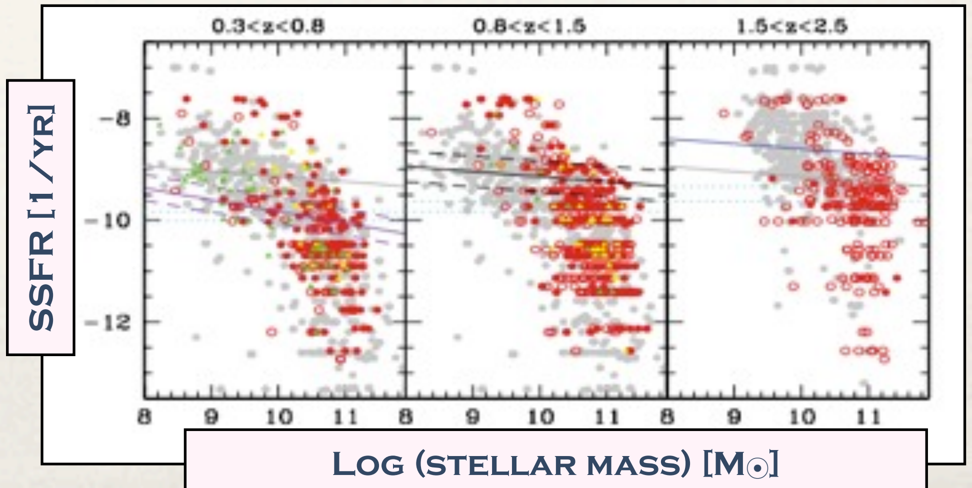

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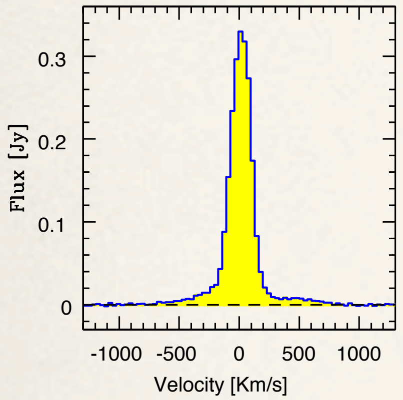

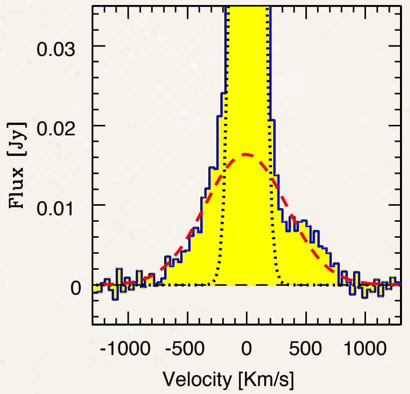

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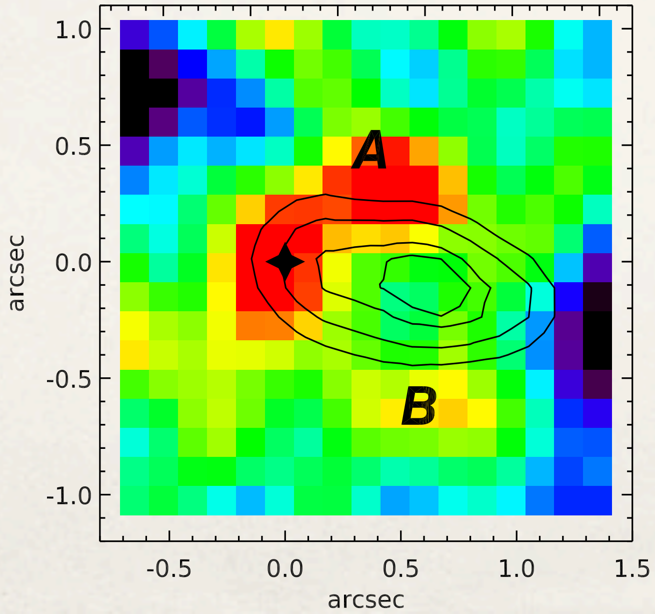

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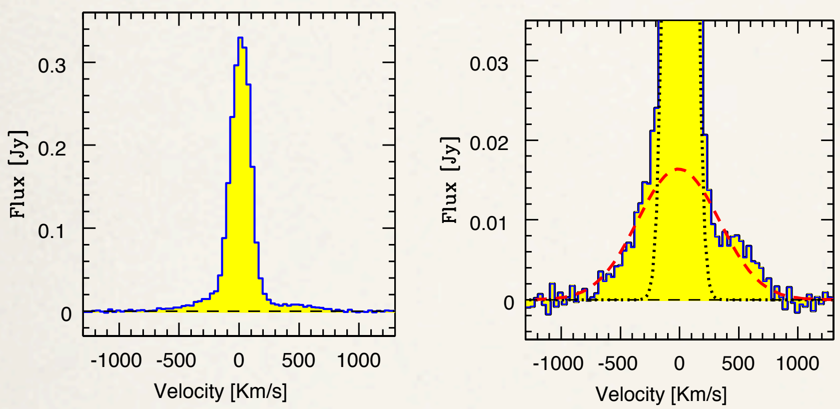

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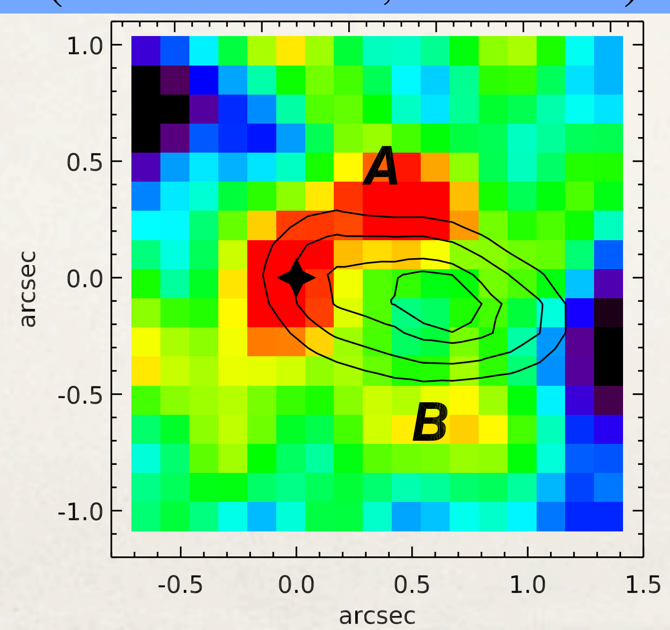

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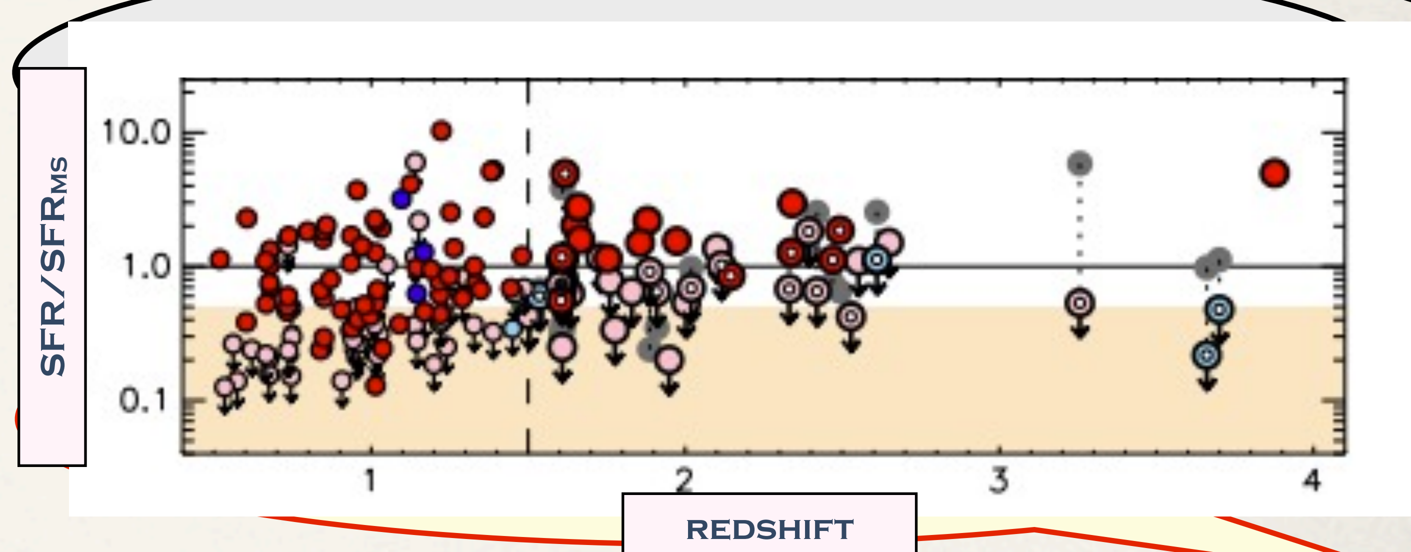
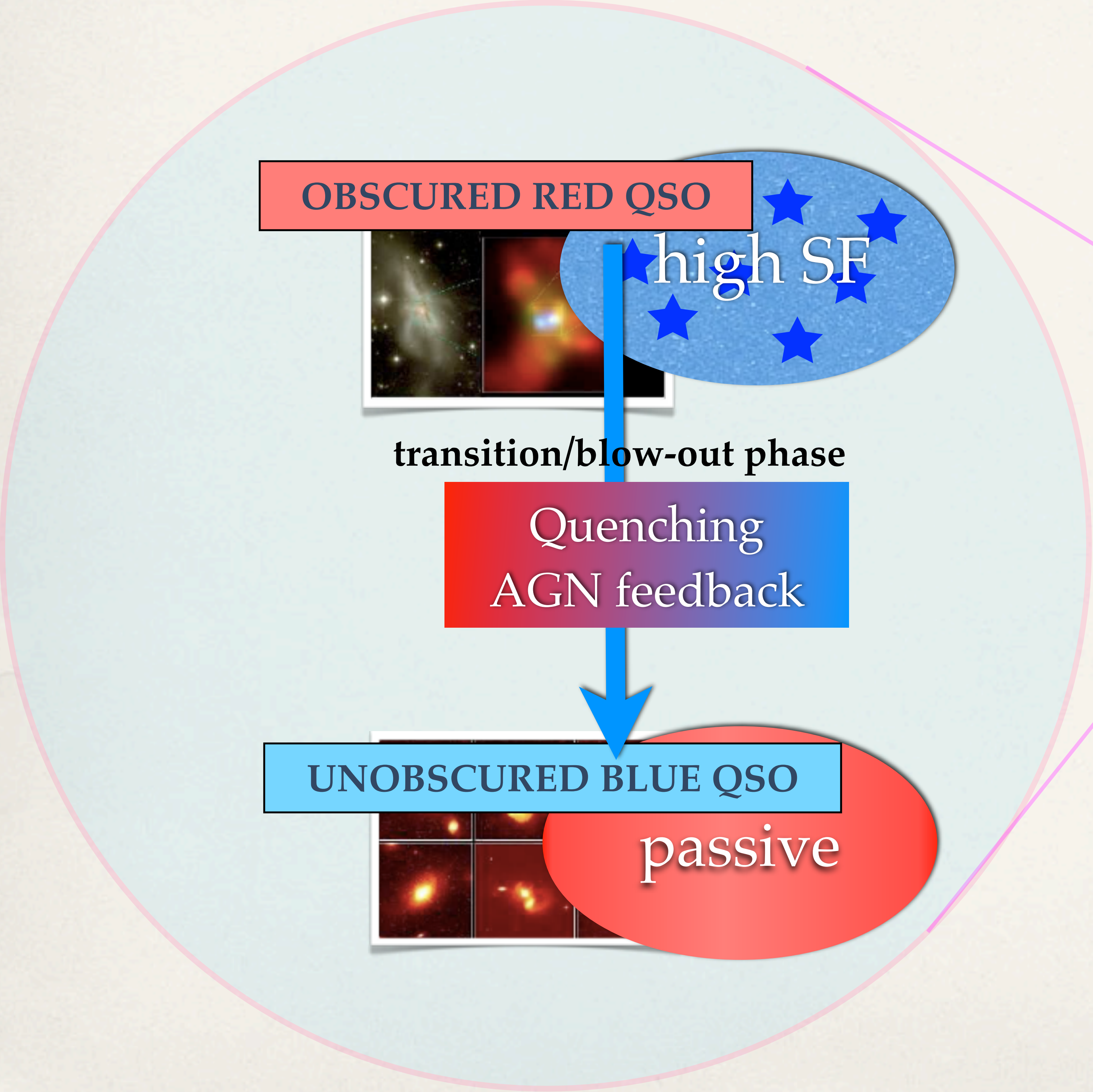
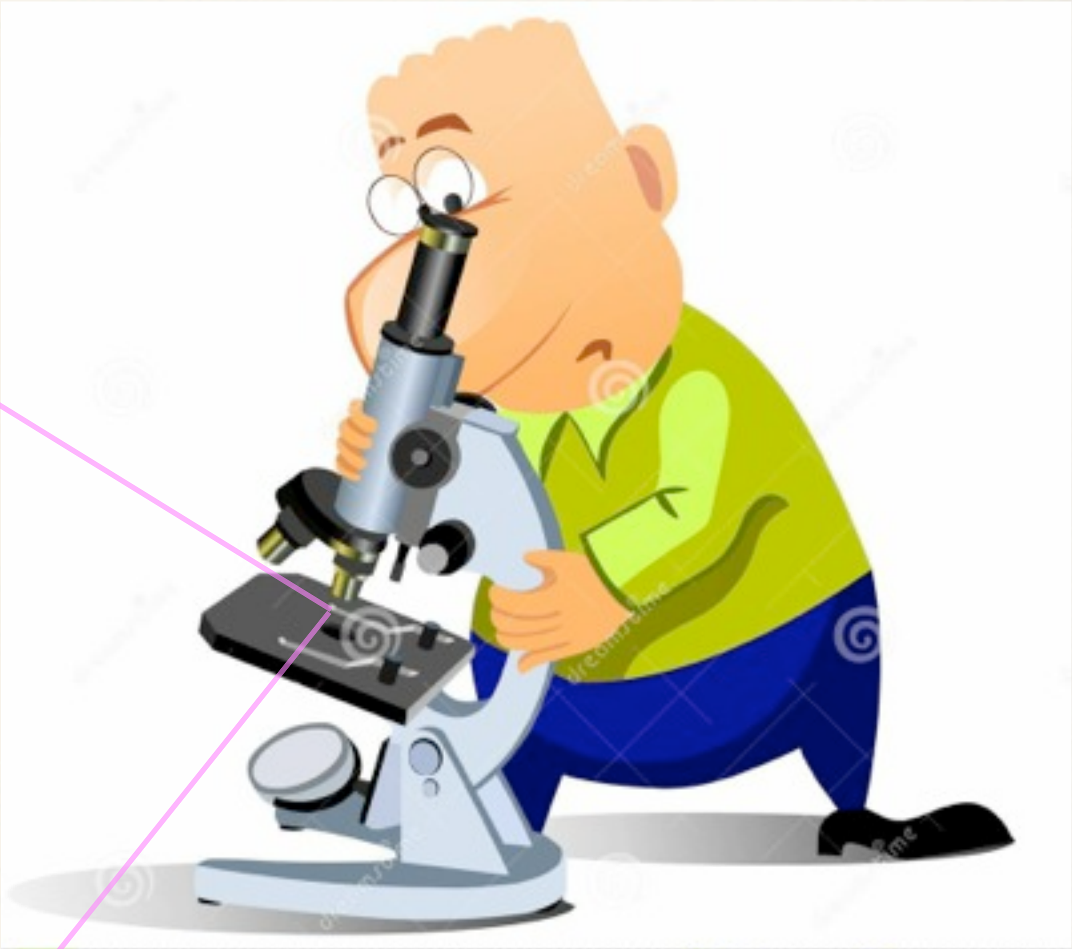


34%–55% of AGNs have SFRs at least a factor of two **below that of the average MS galaxy,** compared to ≈ 15 per cent of all MS galaxies (Mullaney+15)

AGN-galaxy coevolution model





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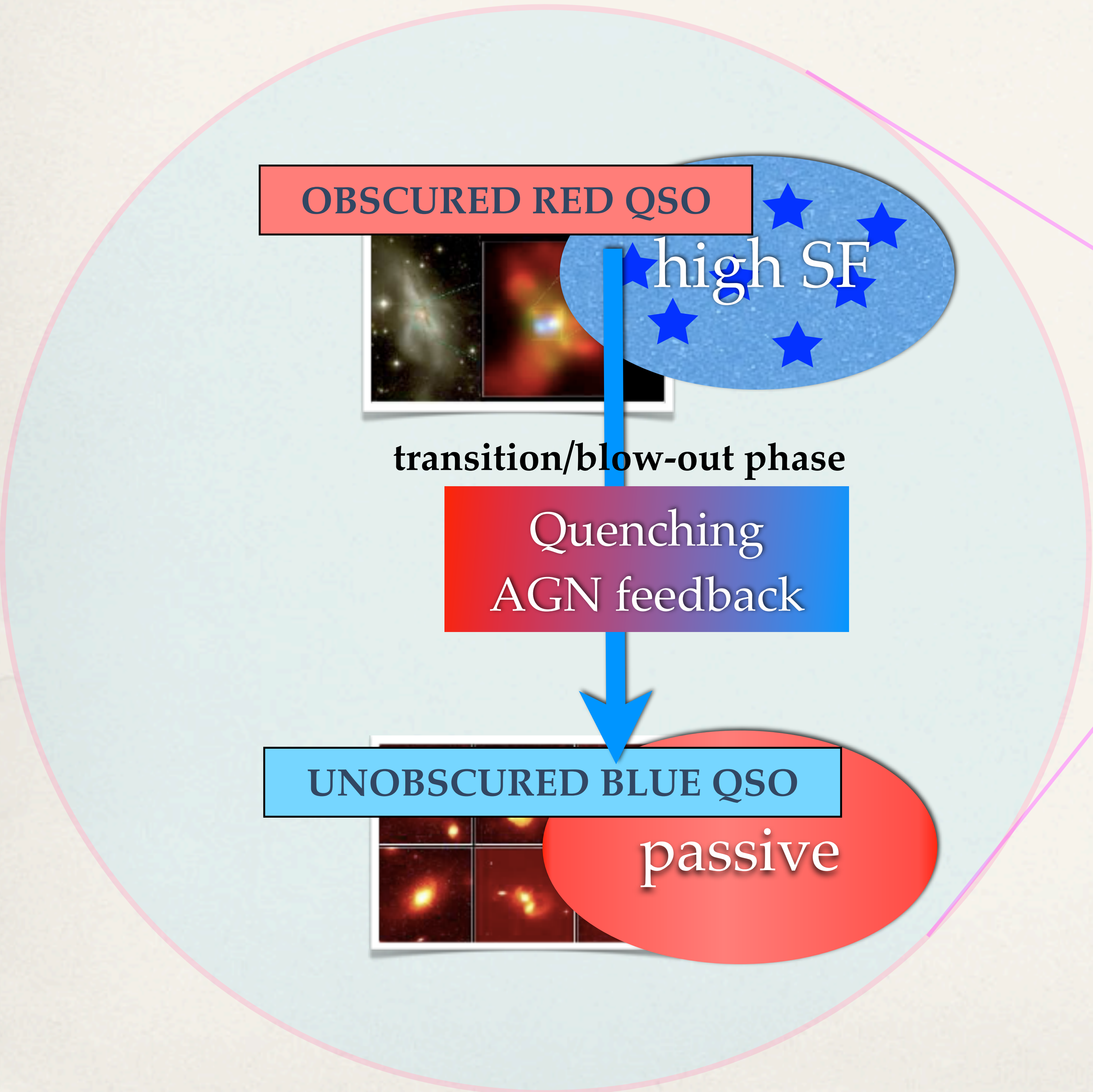
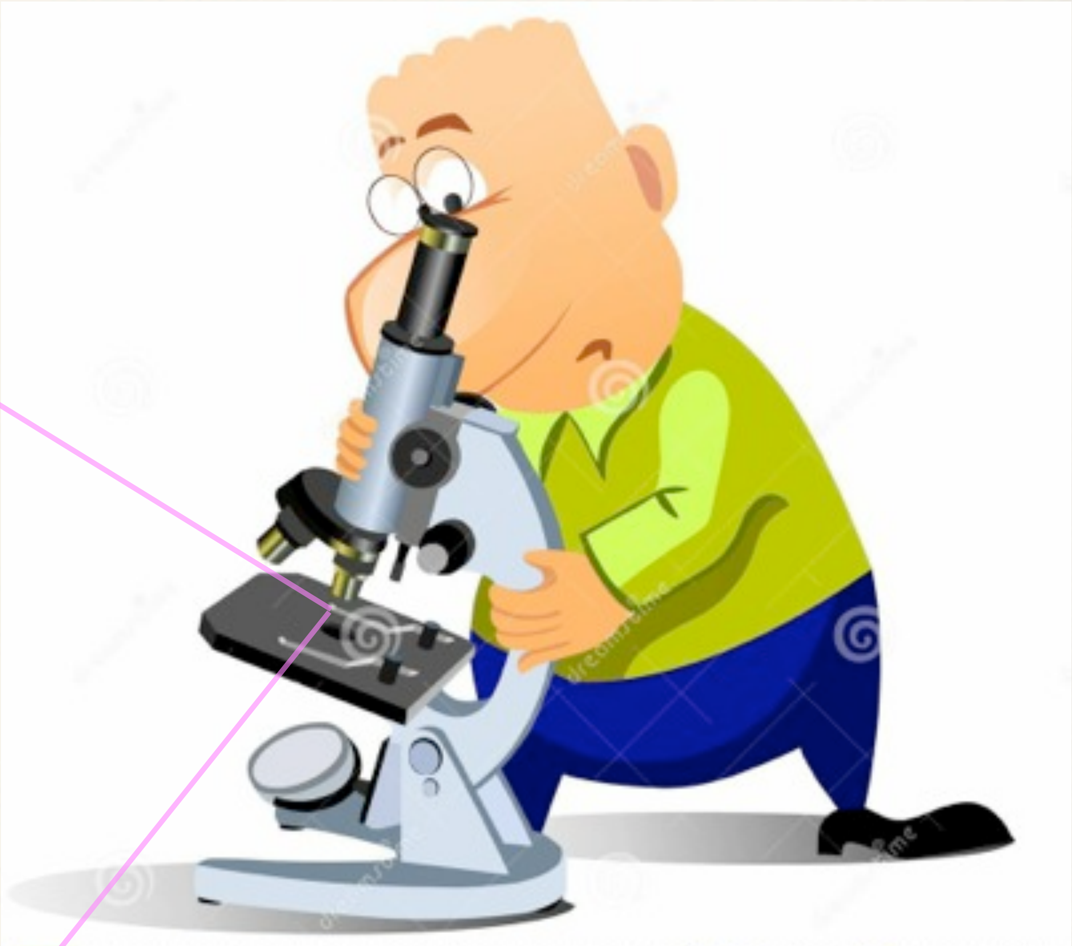
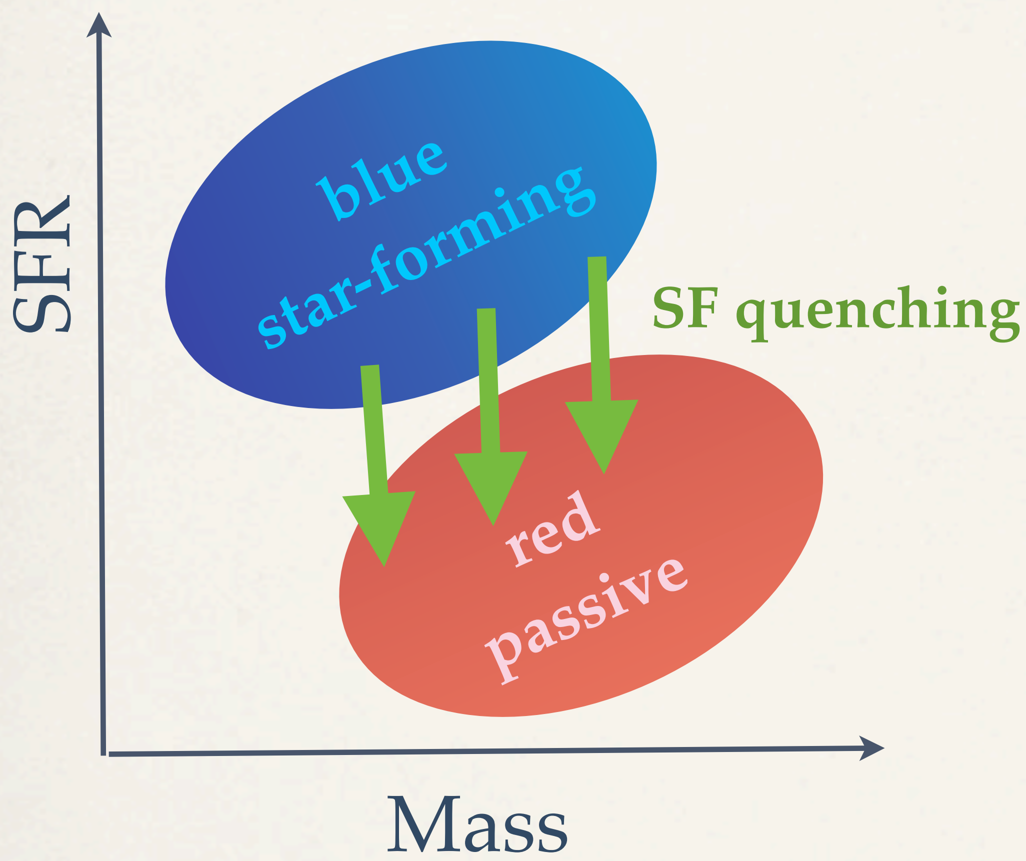


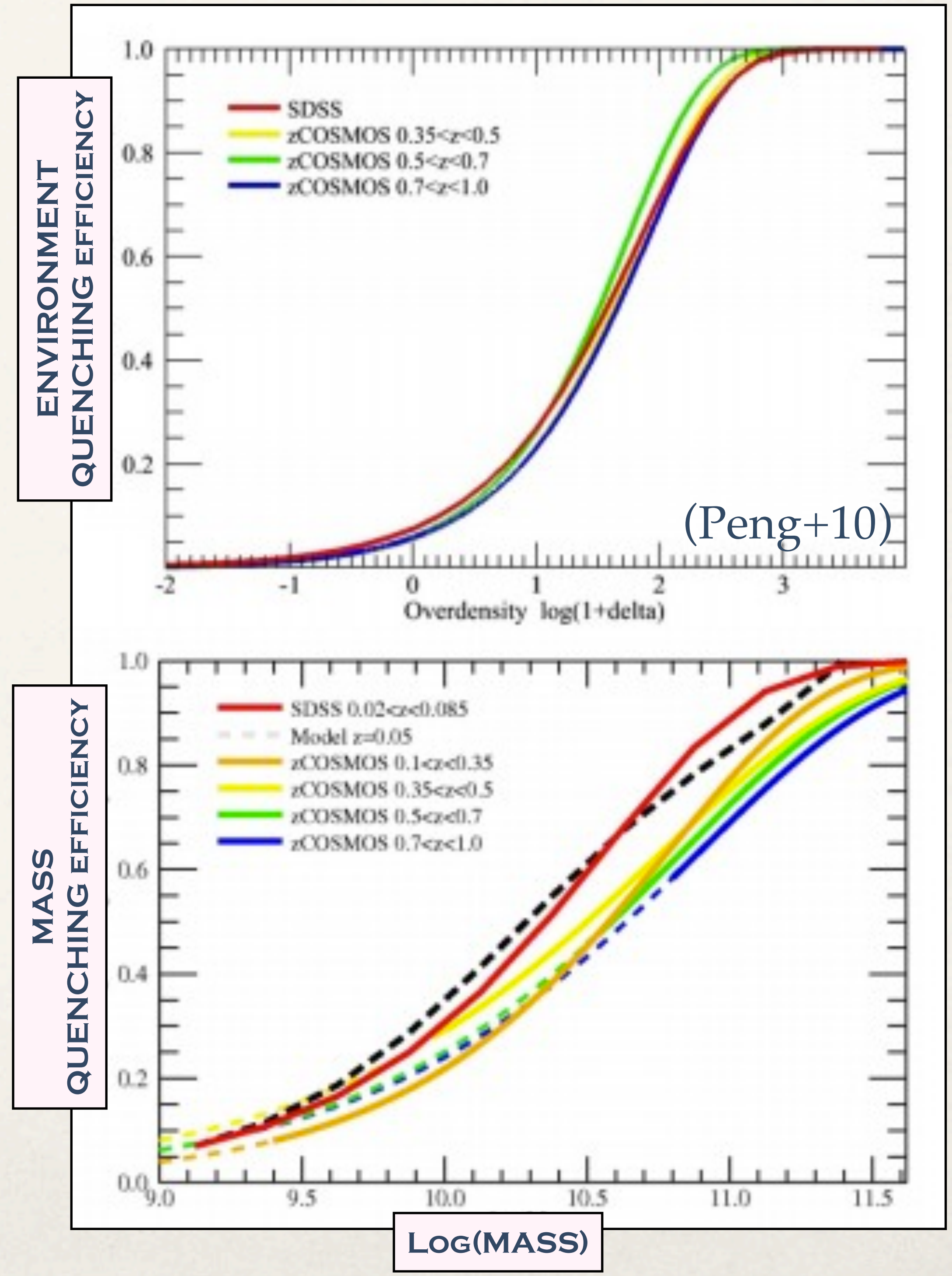


ARE AGN REALLY RESPONSIBLE/ ASSOCIATED TO QUENCHING SF IN GALAXIES? IF YES ... WHICH AGN?

Mass and Environment Quenching

QUENCHING: *the cessation of star formation for any reason*





Peng+10: Mass and Environment quenching are "separable"

- Environment Quenching --> low mass
- Mass Quenching --> high Mass

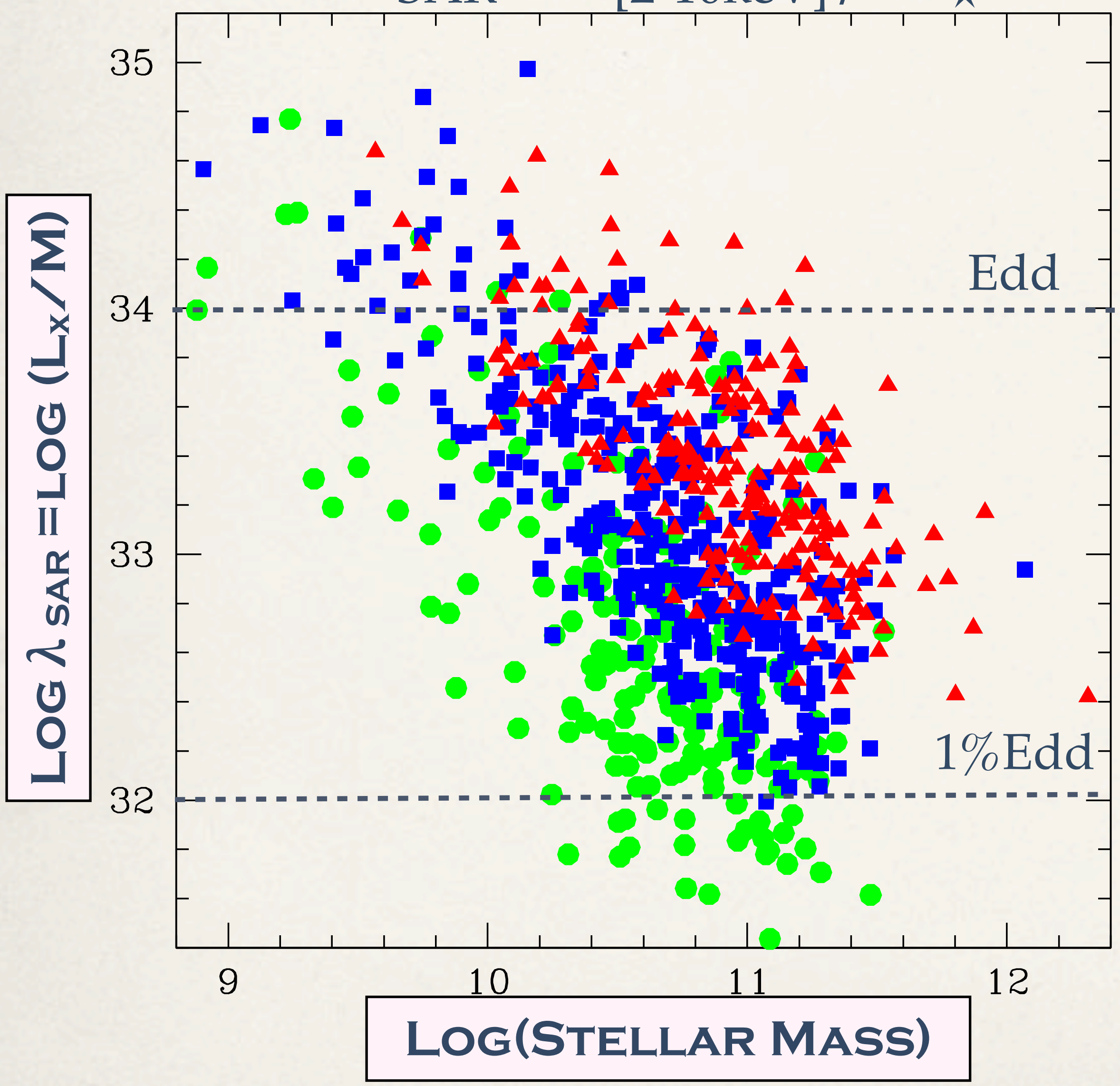
Testing the mass quenching mechanism: XMM-COSMOS Hard X-ray selected sample

927 hard X-ray selected AGN at $0.3<z<2.5$

VIMOS spectroscopic data for more then 50% of the sample

with host galaxy stellar mass ($M_\star$) measured through SED fitting

$\lambda_{SAR} \equiv L_{[2\text{-}10keV]} / M_\star$

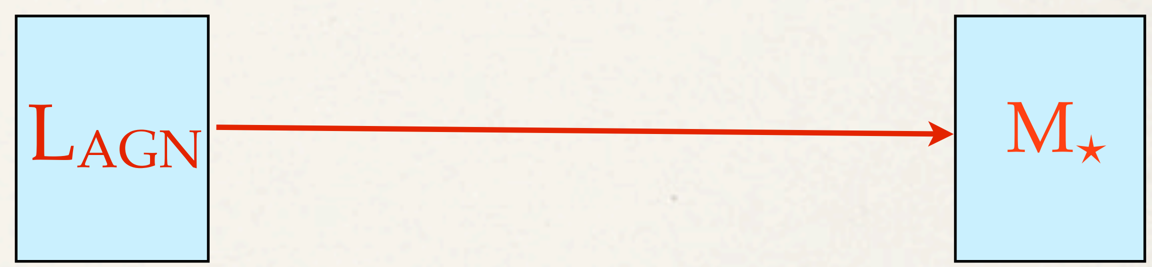


$\lambda_{Edd} \propto L_{bol} / M_{BH} \propto L_x / M_\star \equiv \lambda_{SAR}$

Main computational issue:

FROM a flux-limited AGN sample

TO a host galaxy mass complete sample



(Bongiorno+16)

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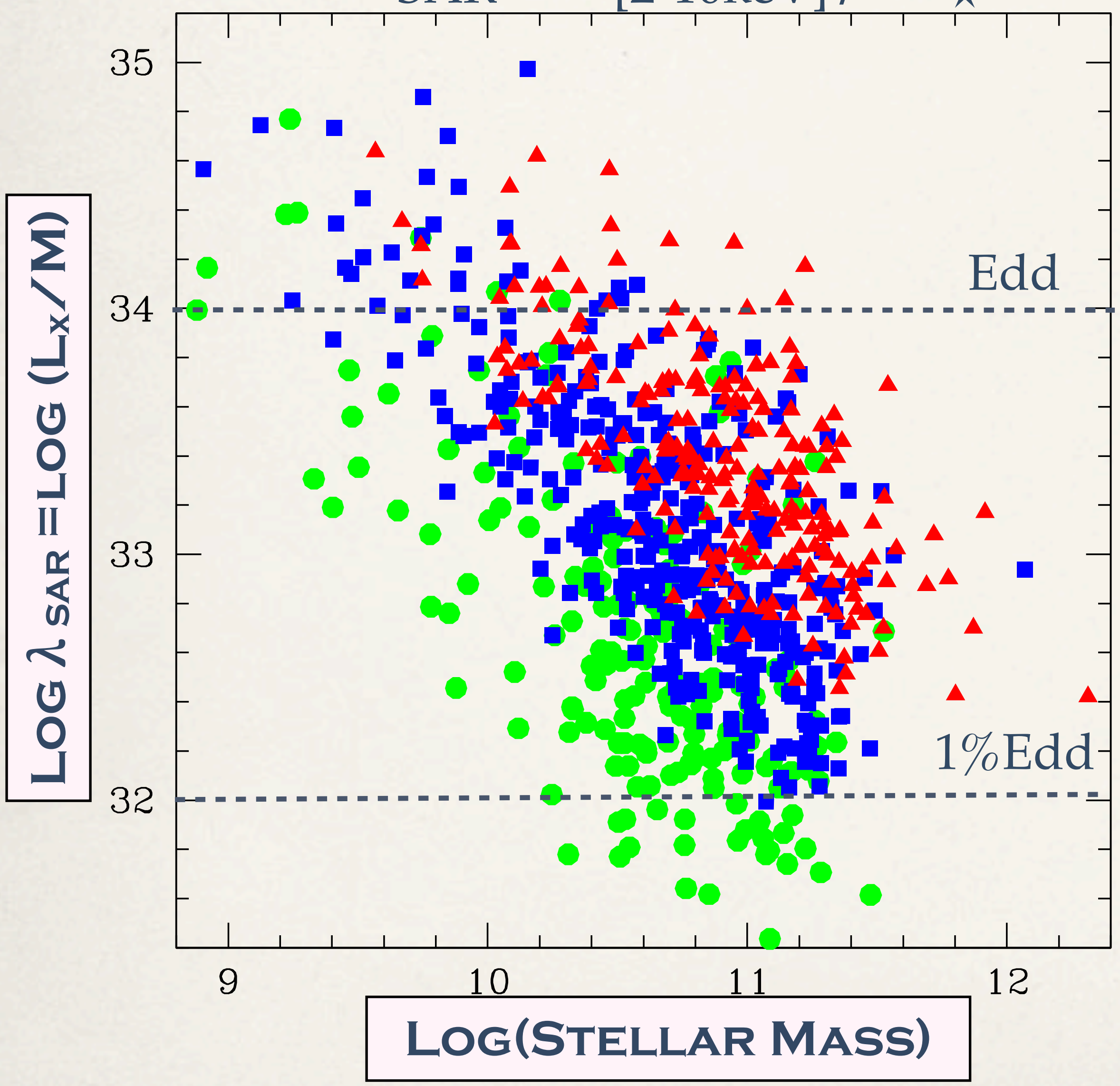

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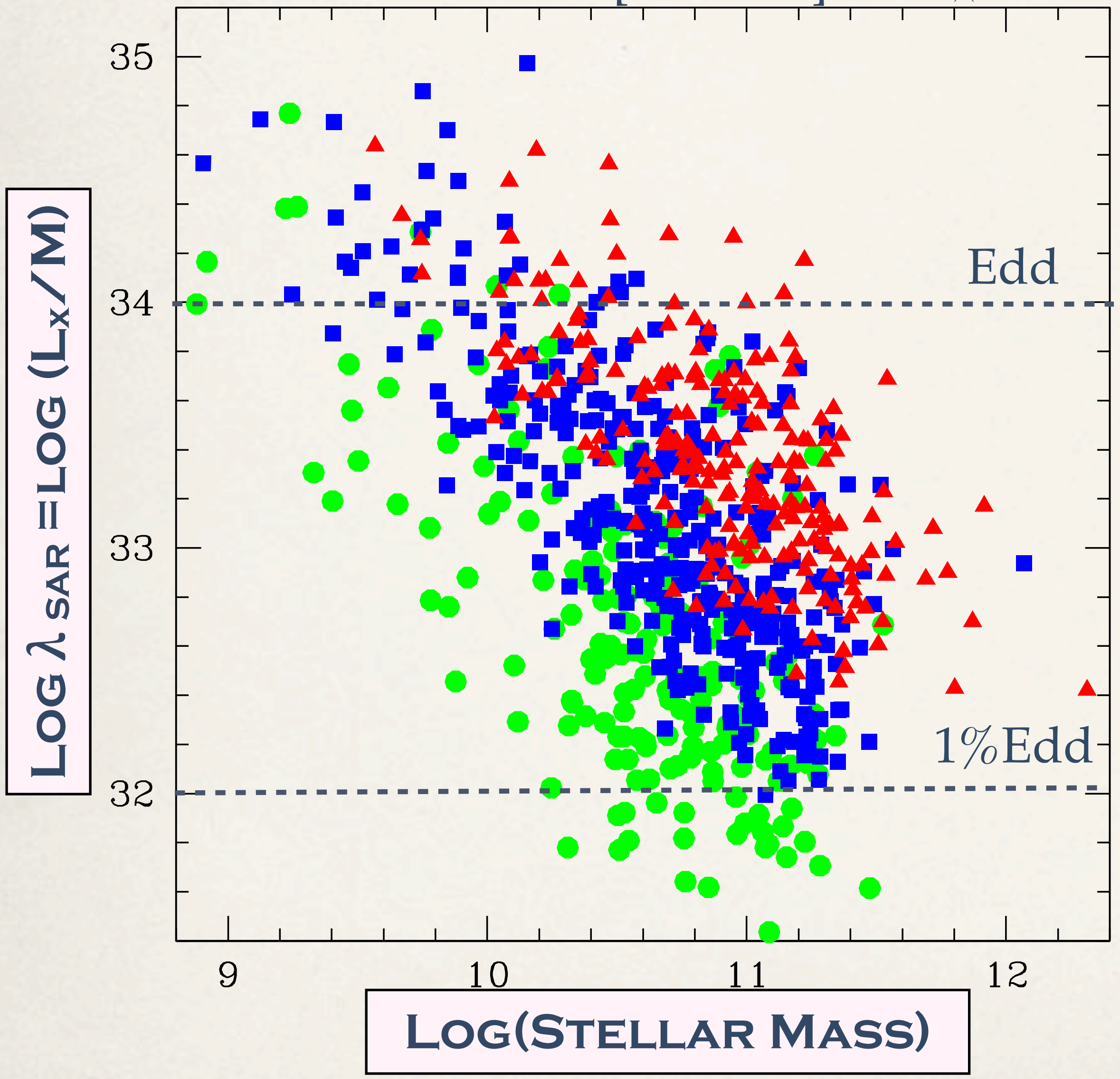

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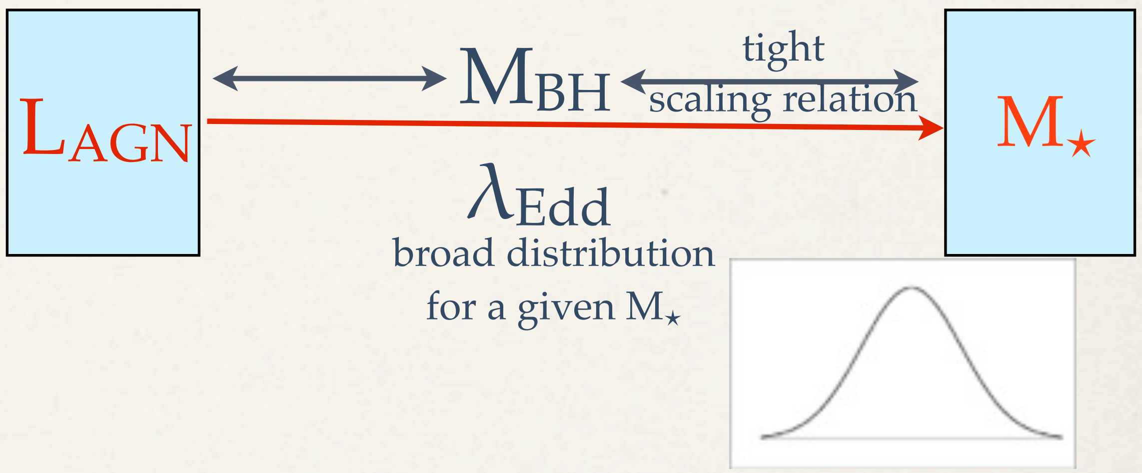

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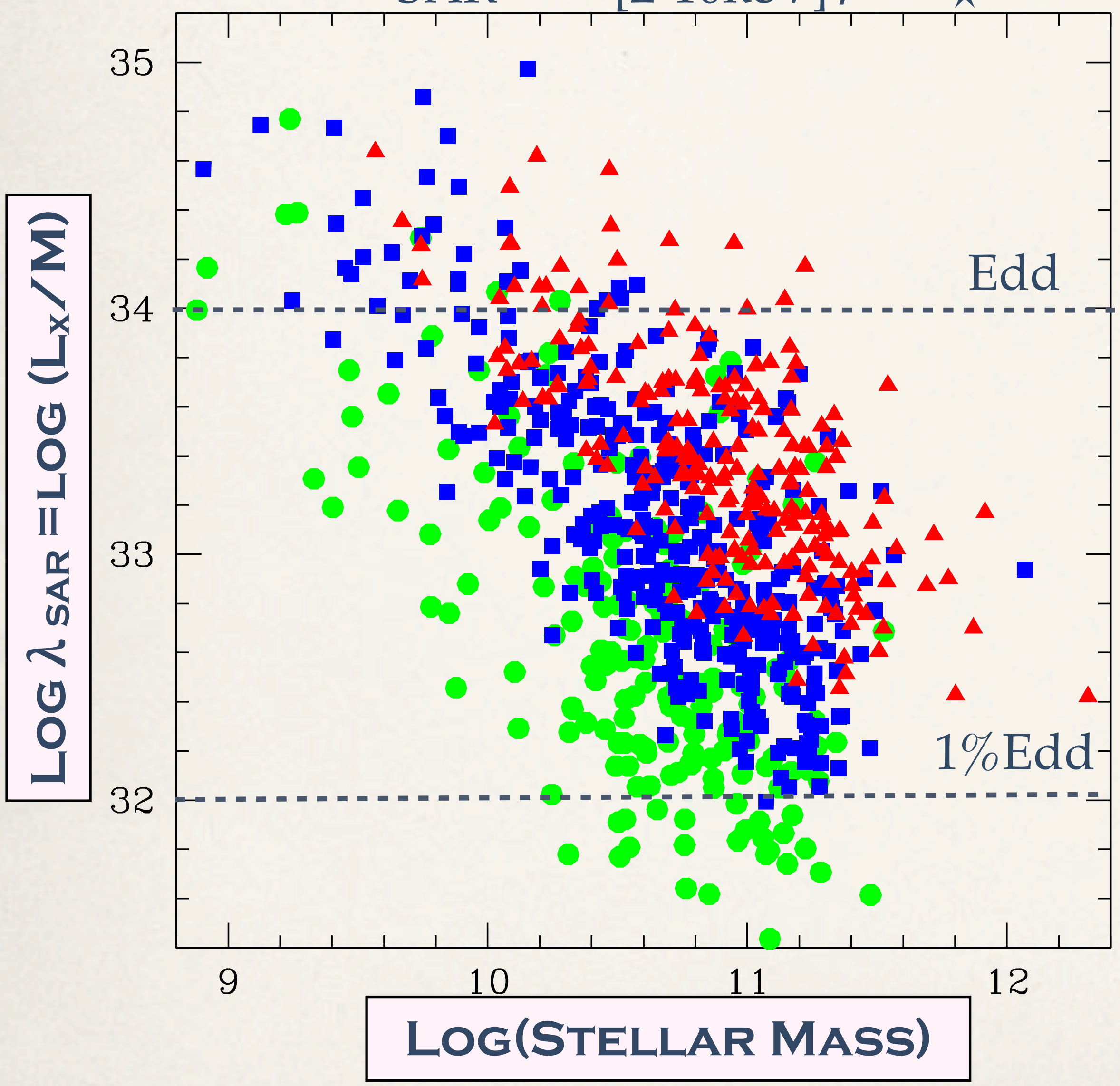

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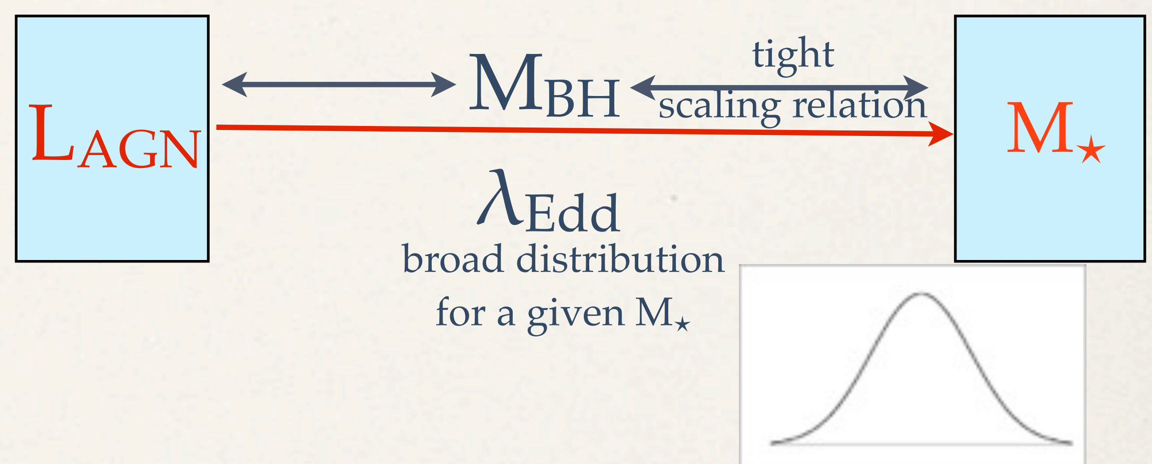
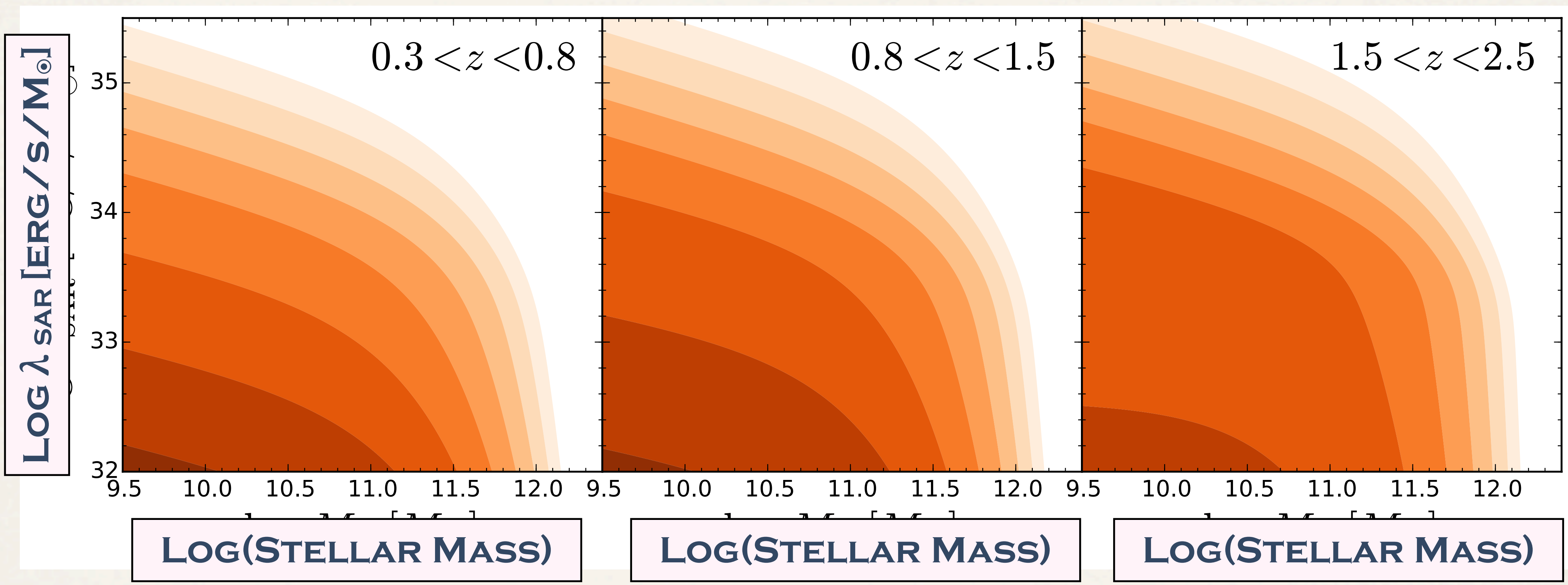


--> Determine HGMF and SARDF simultaneously as a bivariate distribution function of $M_\star$ and λ_{SAR} via the maximum likelihood method

(Schulze & Wisotzki 2010; Schulze et al 2015)

Bivariate distribution function



$$\Psi(M_*,\lambda_{SAR},z)=\Psi^* f_{\lambda_{SAR}}(\lambda_{SAR},M_*,z)f_*(M_*,z)f_z(z)$$

$$\Phi(\lambda_{SAR},z)=\frac{dN}{dVd\log\lambda_{SAR}}=\int\Psi(M_*,\lambda_{SAR},z)dM_*$$

Specific accretion rate Distribution Function SARDF

$$\Phi(M_*,z)=\frac{dN}{dVd\log N}=\int\Psi(M_*,\lambda_{SAR},z)d\log\lambda_{SAR}$$

Host Galaxy Mass Function HGMF

(Bongiorno+16)

Specific Accretion rate distribution function (SARDF)

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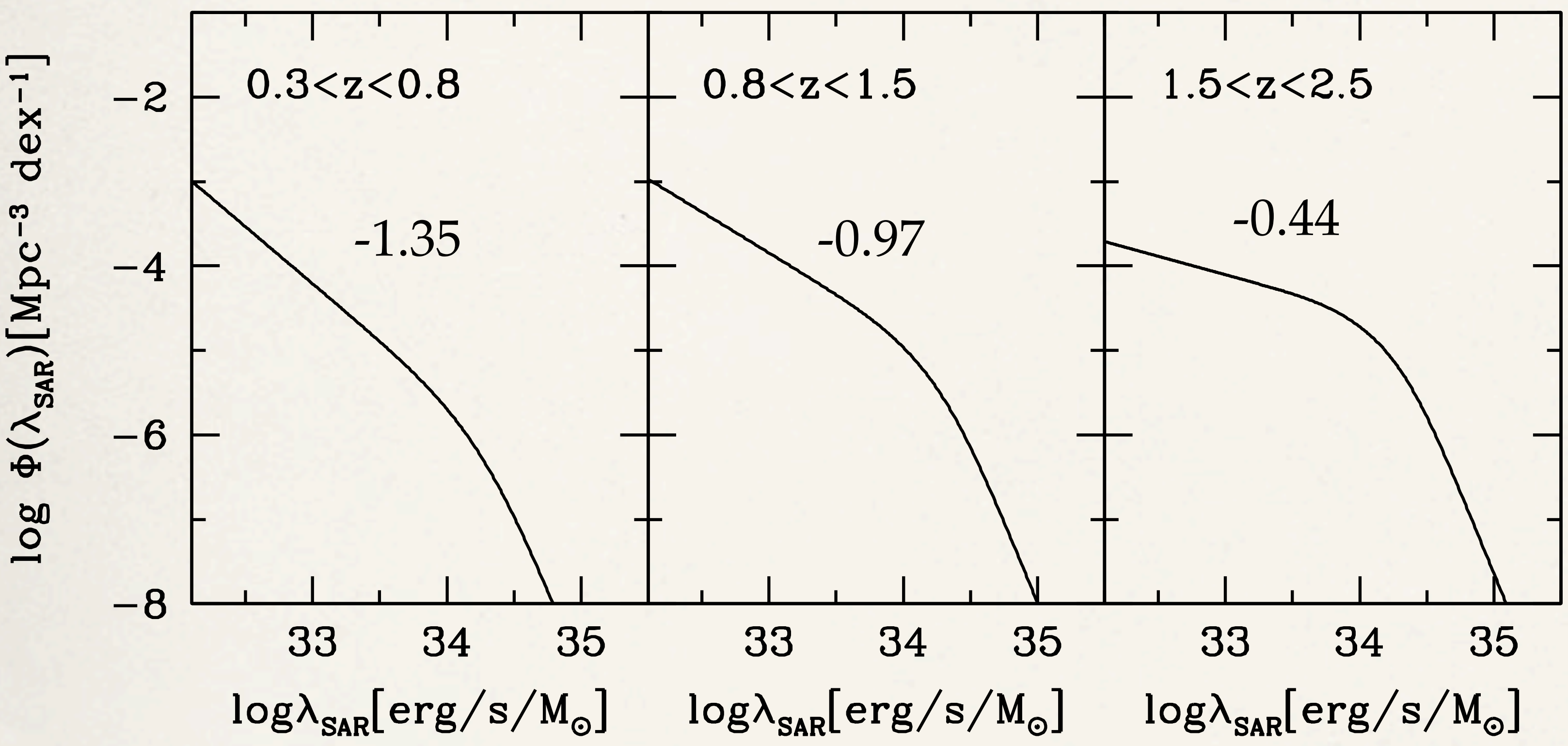
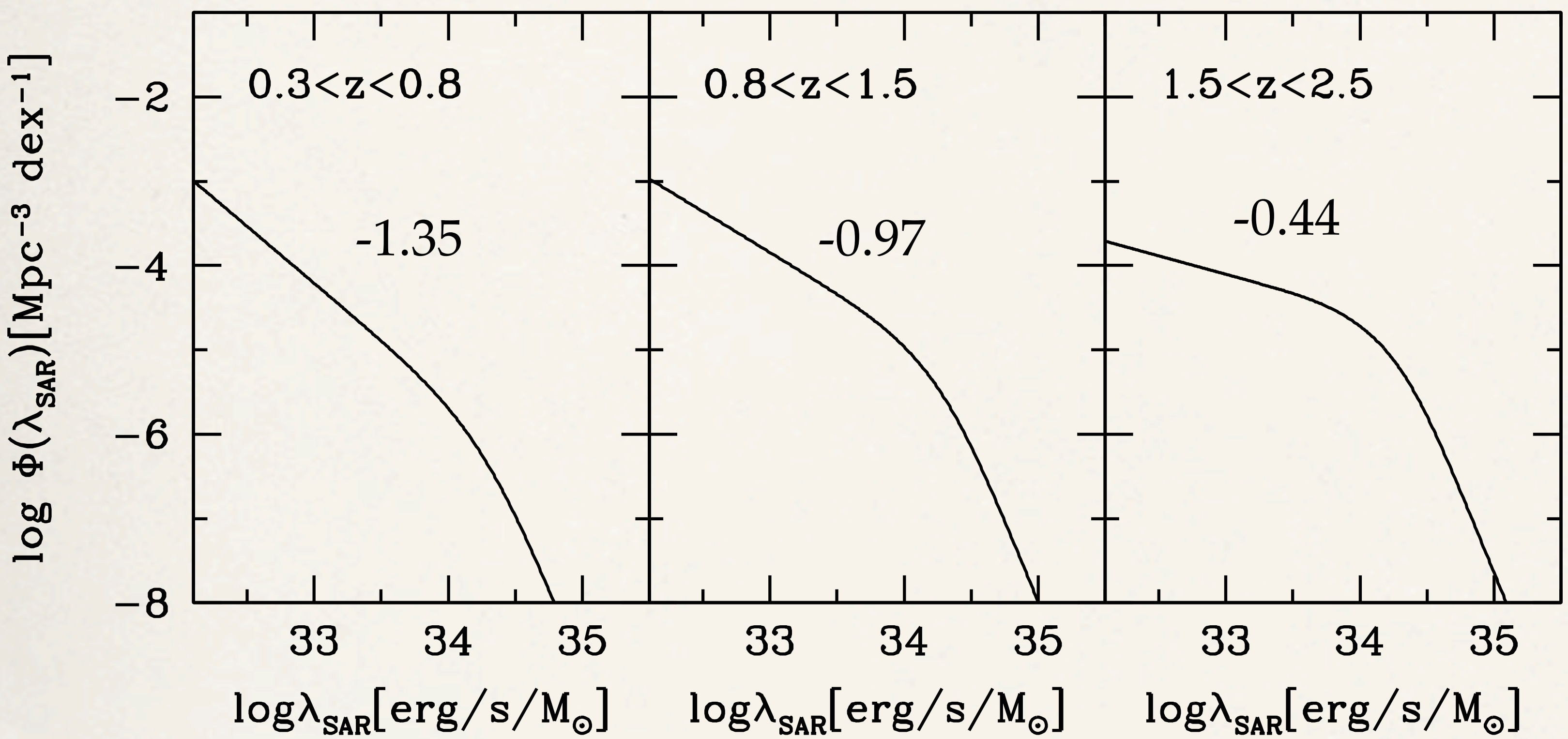


- double power law with a break above Edd
- low λ_{SAR} slope flattening with z from -1.35 to -0.44
- normalization increasing with z
- mass dependent λ^*_{SAR} (but z-indipendent)

(Bongiorno+16)

Specific Accretion rate distribution function (SARDF)

$$\Phi(\lambda_{SAR}, z) = \frac{dN}{dV d\log\lambda_{SAR}} = \int \Psi(M_*, \lambda_{SAR}, z)\, dM_*$$



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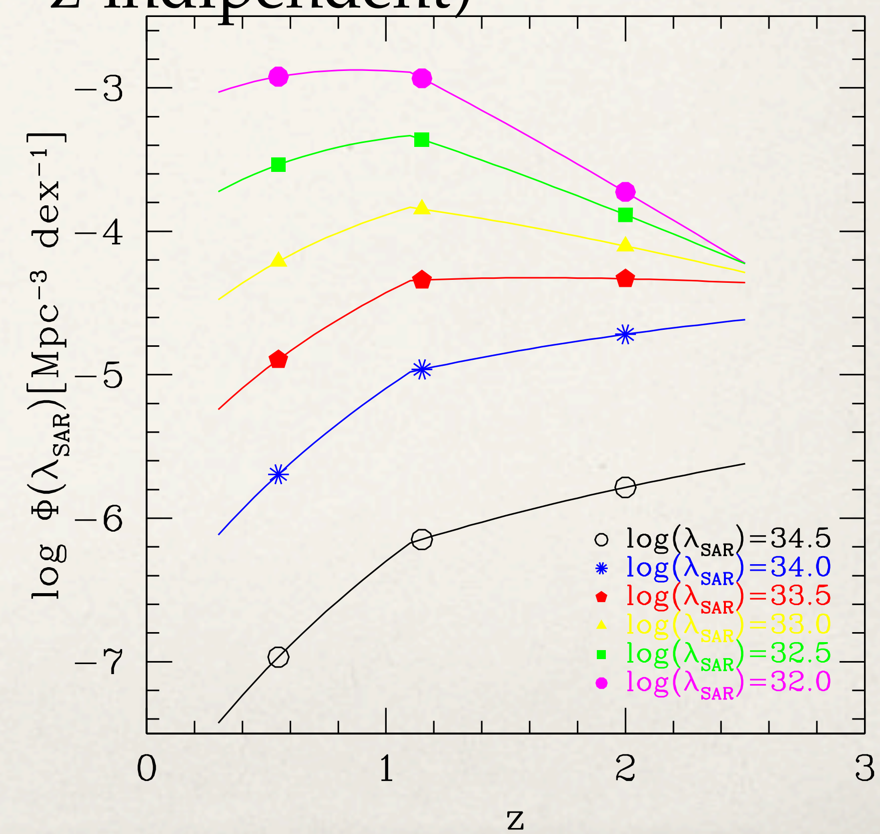
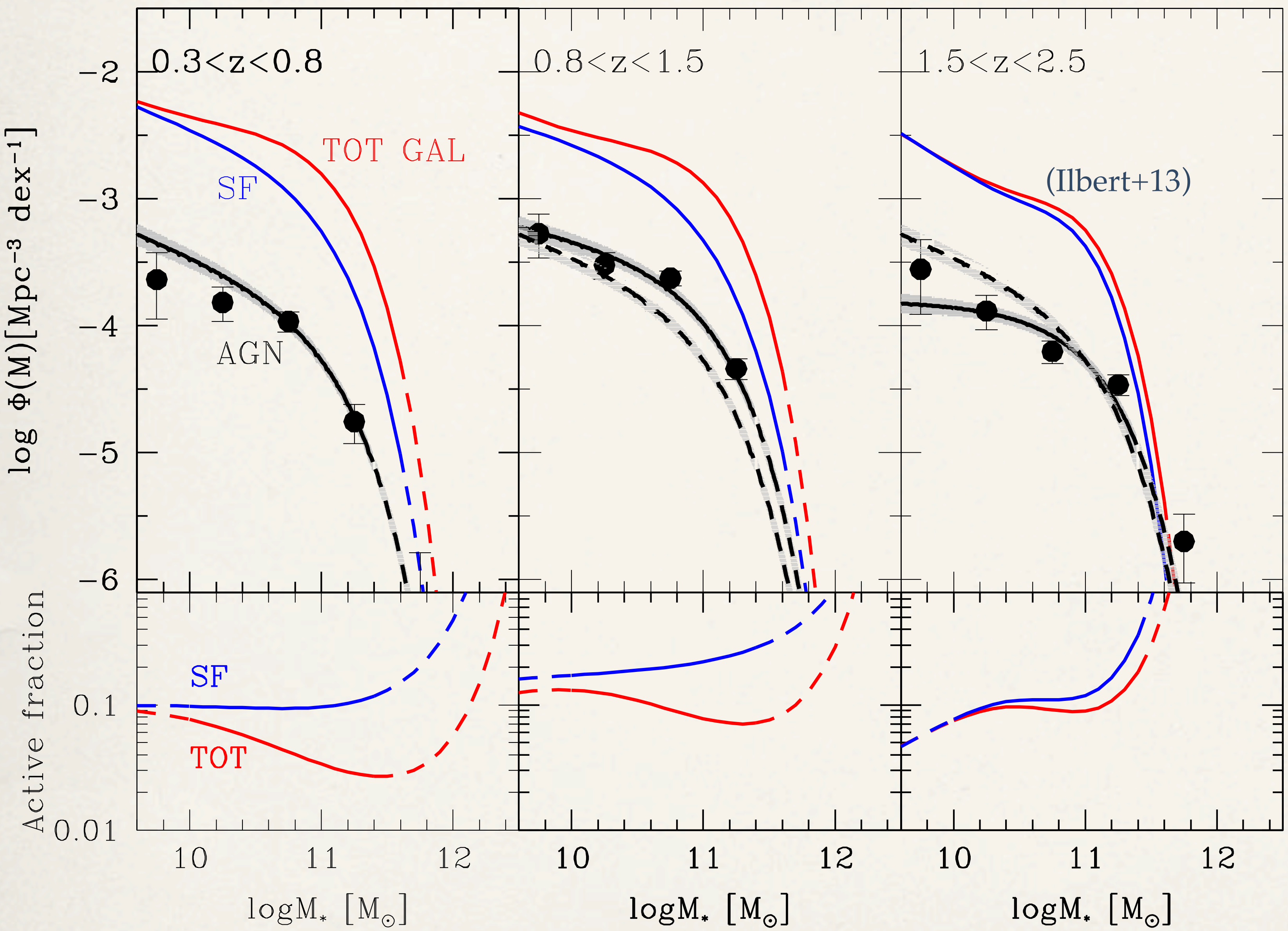
Downsizing in $\Phi(\lambda_{SAR})$:
high λ_{SAR} objects peak at higher z compared to low λ_{SAR} objects



(Bongiorno+16)

Host Galaxy mass function (HGMF)

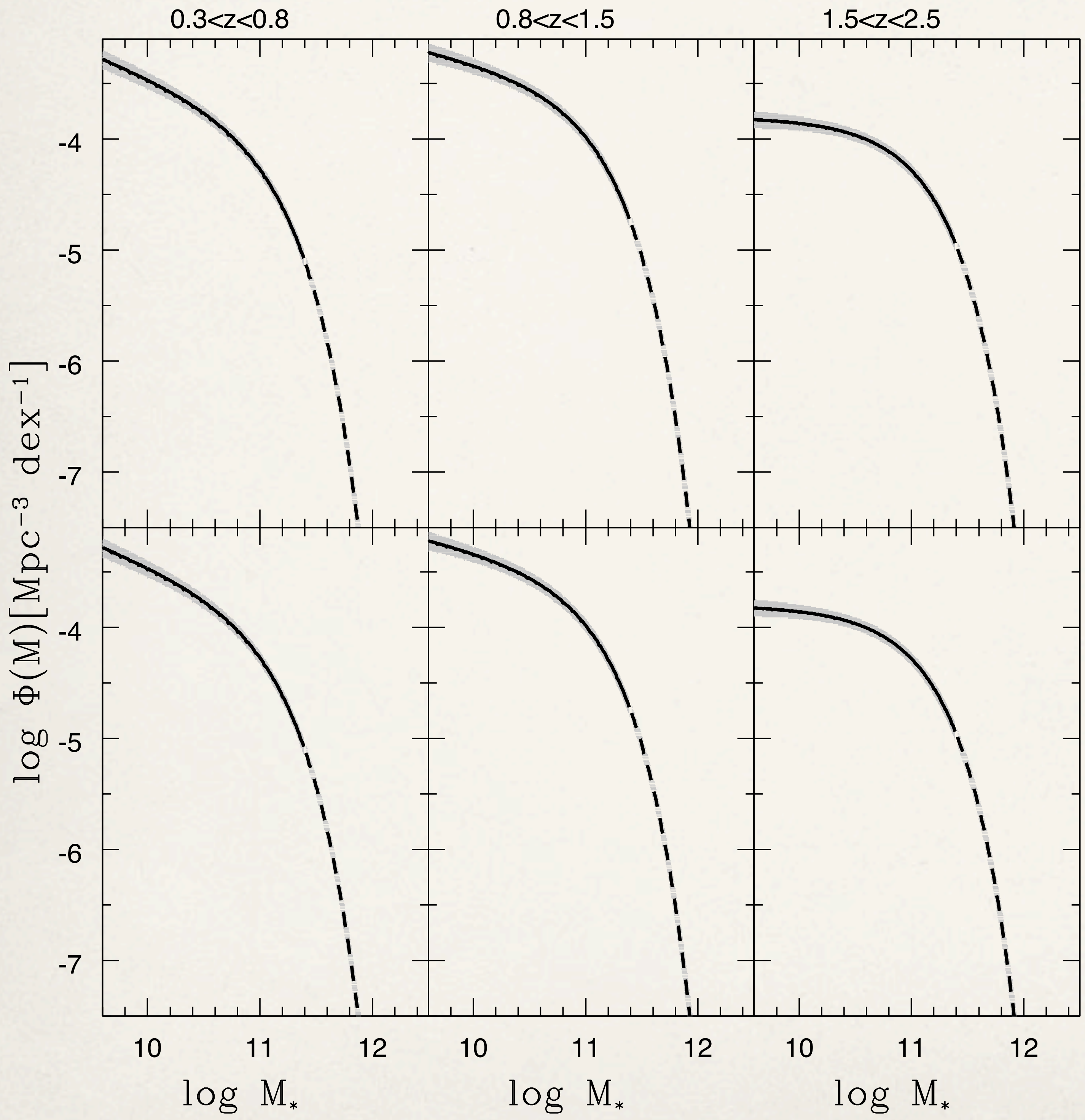
$$\Phi(M_*, z) = \frac{dN}{dV d\log N} = \int \Psi(M_*, \lambda_{SAR}, z)\, d\log\lambda_{SAR}$$



- Schechter function
- low mass slope flattening with z (i.e. -0.42, -0.25, -0.03)
- active fraction ~ constant (10%-20%) with Mass

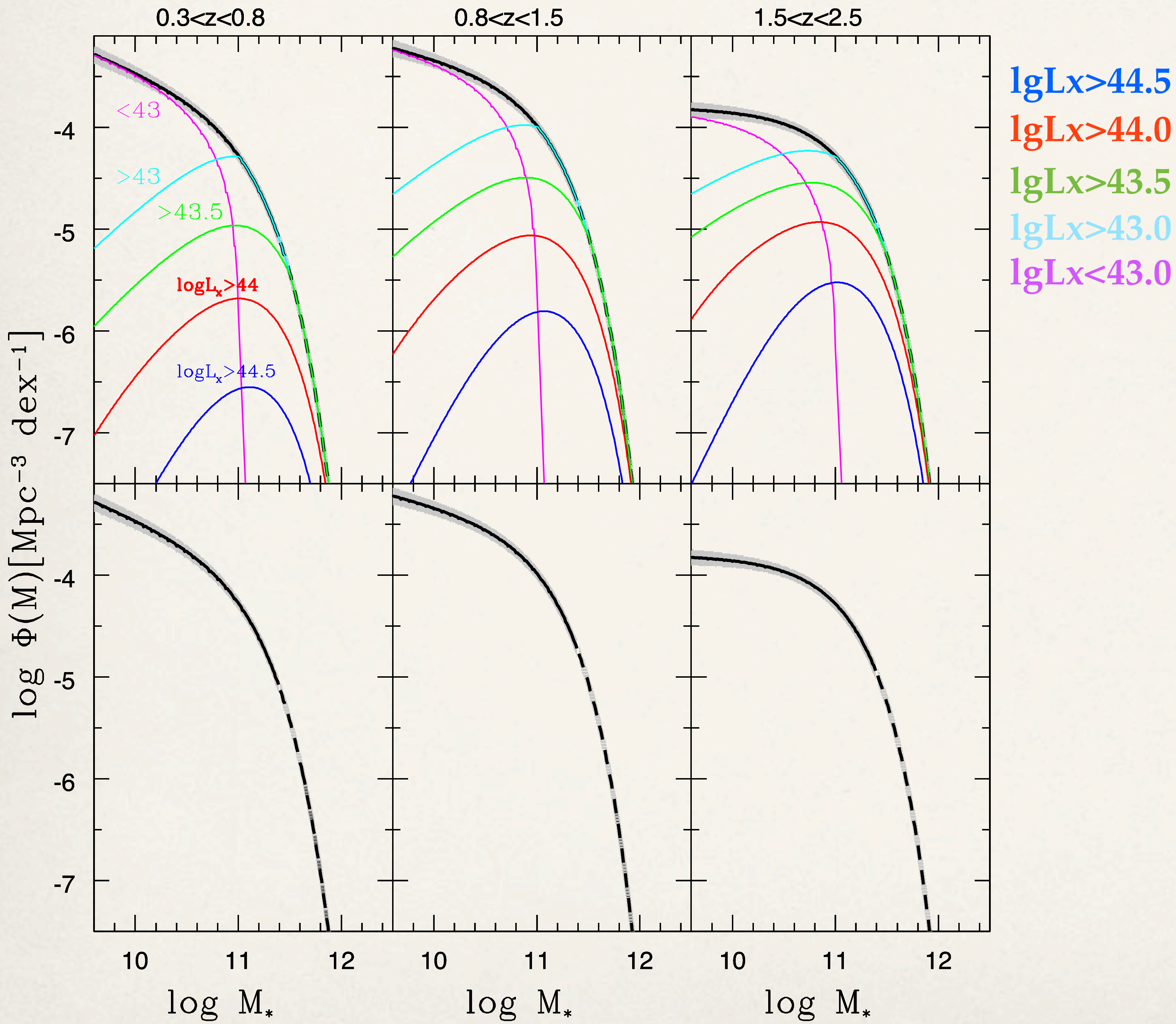
(Bongiorno+16)

HGMF in Lx and λ_{SAR} bins



(Bongiorno+16)

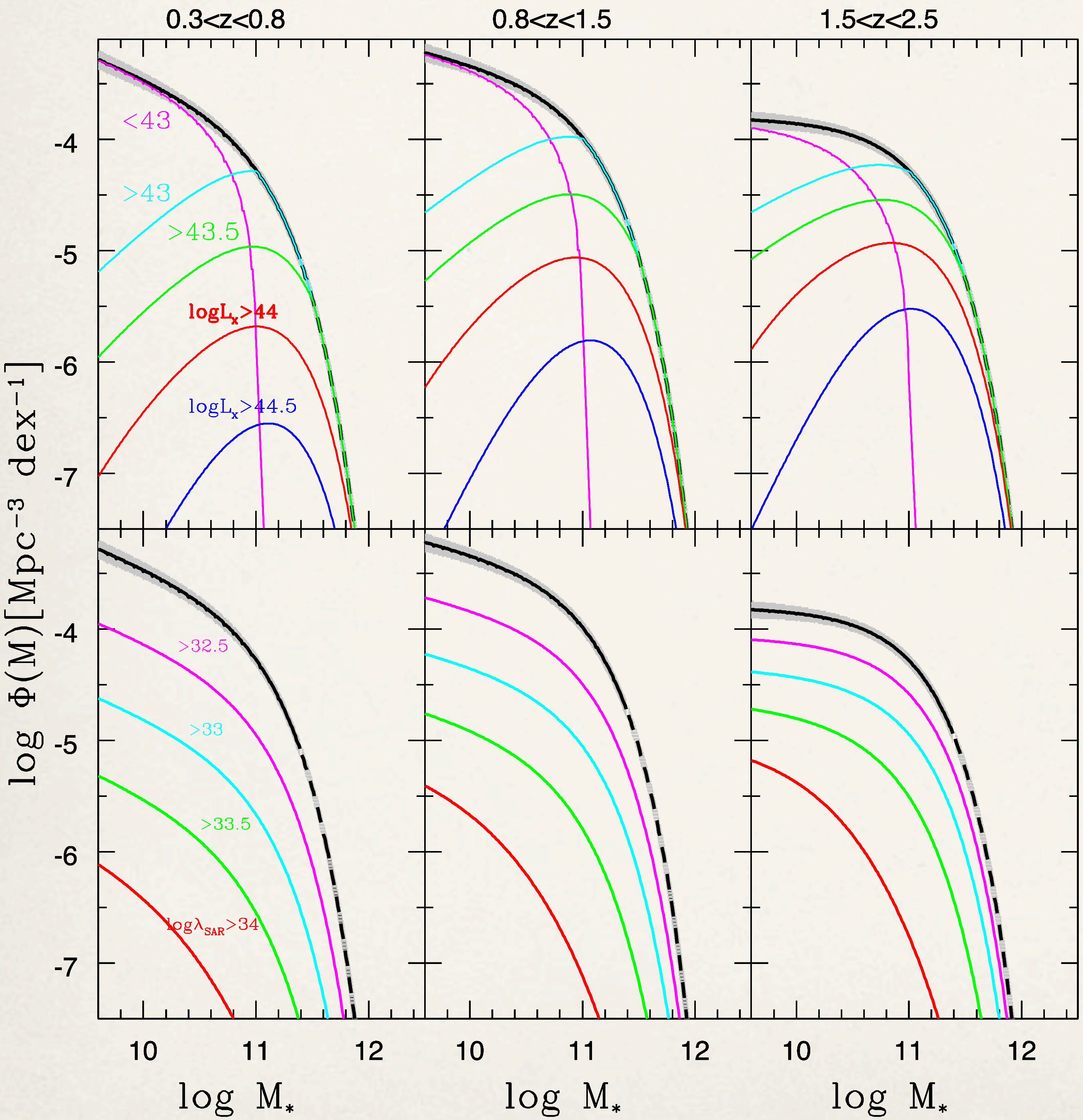
HGMF in Lx and λ_{SAR} bins



when integrated over the whole λ_{SAR} range,
low-luminosity AGN are mainly hosted in less massive galaxies
and
high luminosity AGN in more massive galaxies

(Bongiorno+16)

HGMF in Lx and λ_{SAR} bins



lgLx>44.5
lgLx>44.0
lgLx>43.5
lgLx>43.0
lgLx<43.0

when integrated over the whole λ_{SAR} range,
low-luminosity AGN are mainly hosted in less massive galaxies
and
high luminosity AGN in more massive galaxies

lgλ>34.0
lgλ>33.5
lgλ>33.0
lgλ>32.5

no trend in λ_{SAR}

(Bongiorno+16)

Mass function of the transient population (Peng et al., 2010)

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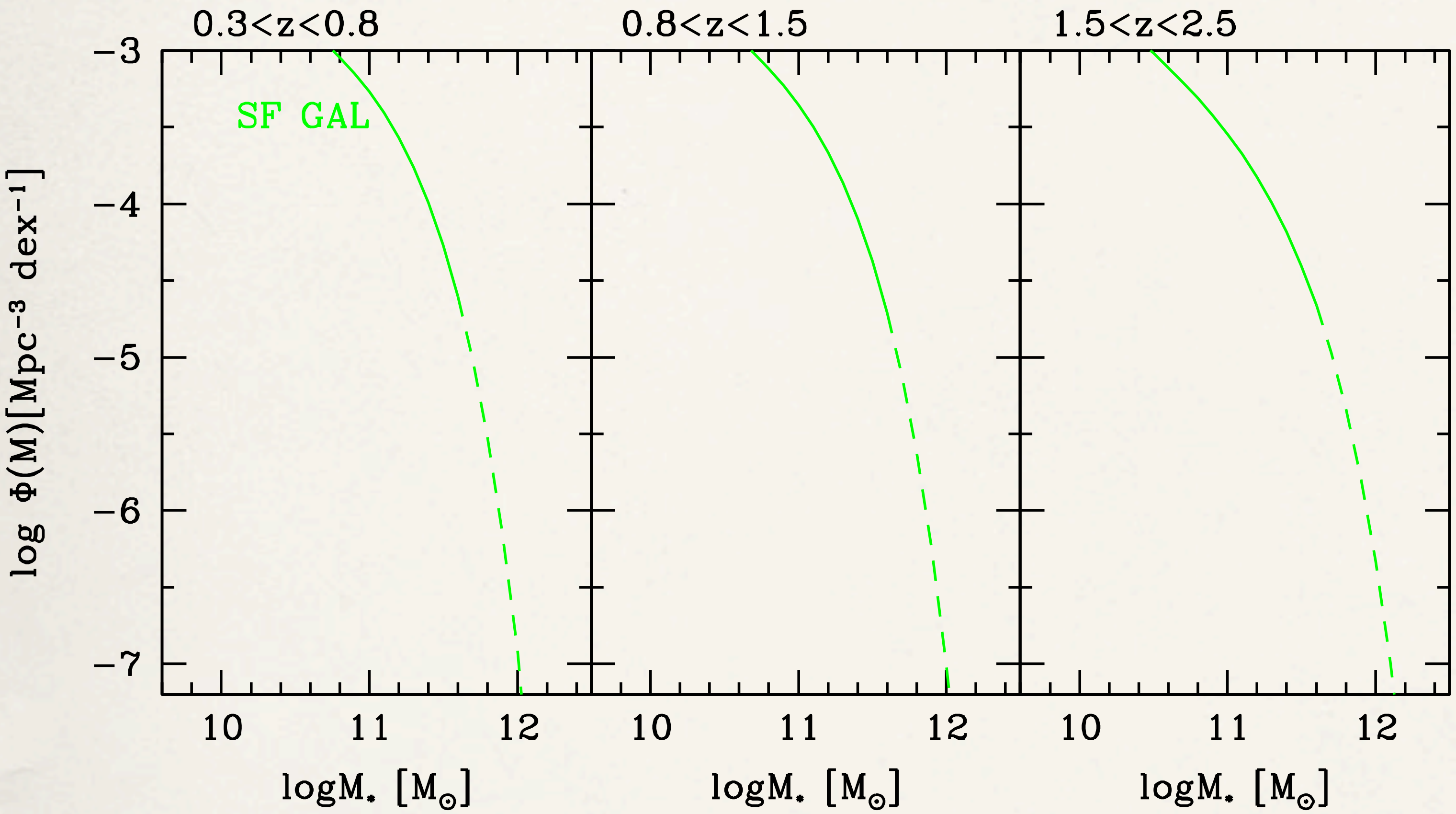
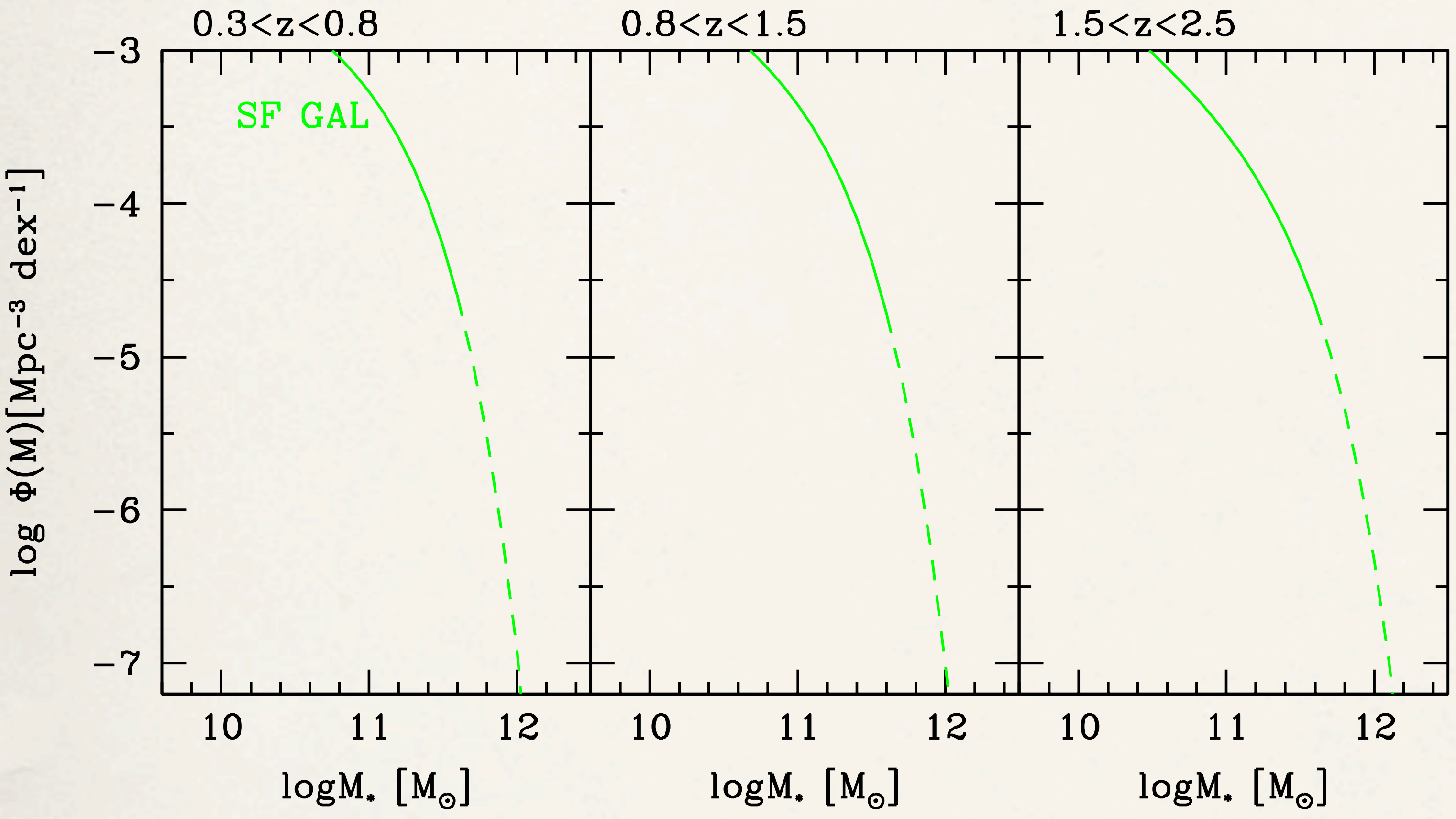


Φ_{trans} is a Schechter function

$$M^*_{\rm trans} = M^*_{\rm blue}$$
$$\alpha_{s,\rm trans} = \alpha_{s,\rm blue} + (1+\beta)$$
$$\phi^*_{\rm trans} = \phi^*_{\rm blue}\ {\rm sSFR}(t)|_{M^*}\ \tau_{\rm trans}$$

Mass function of the transient population (Peng et al., 2010)



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$$sSFR(M,z) = A\left(\frac{M}{10^{10.5}M_{sun}}\right)^{\beta}(1+z)^3\,Gyr^{-1}$$

Lilly et al., 2013

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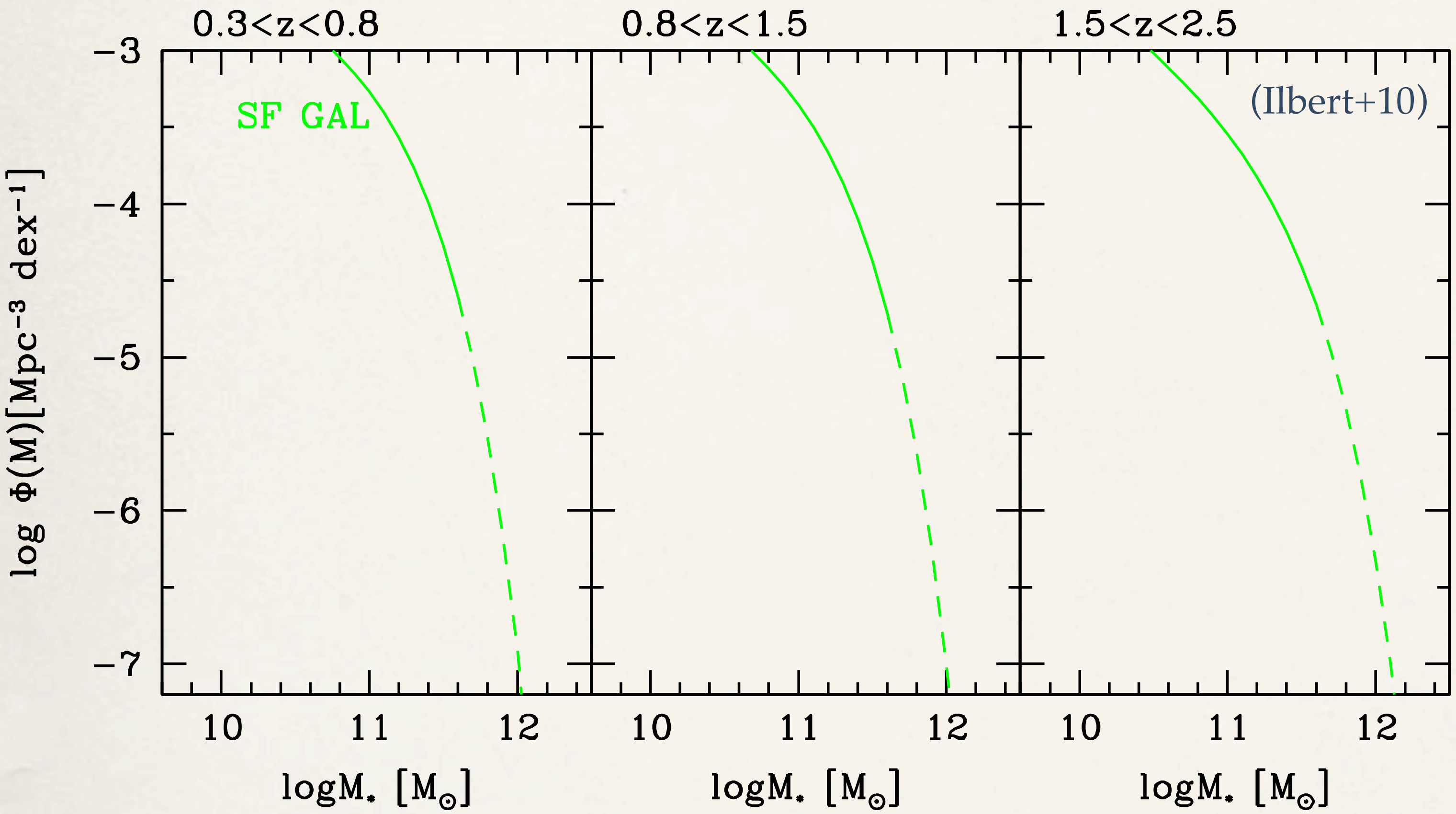

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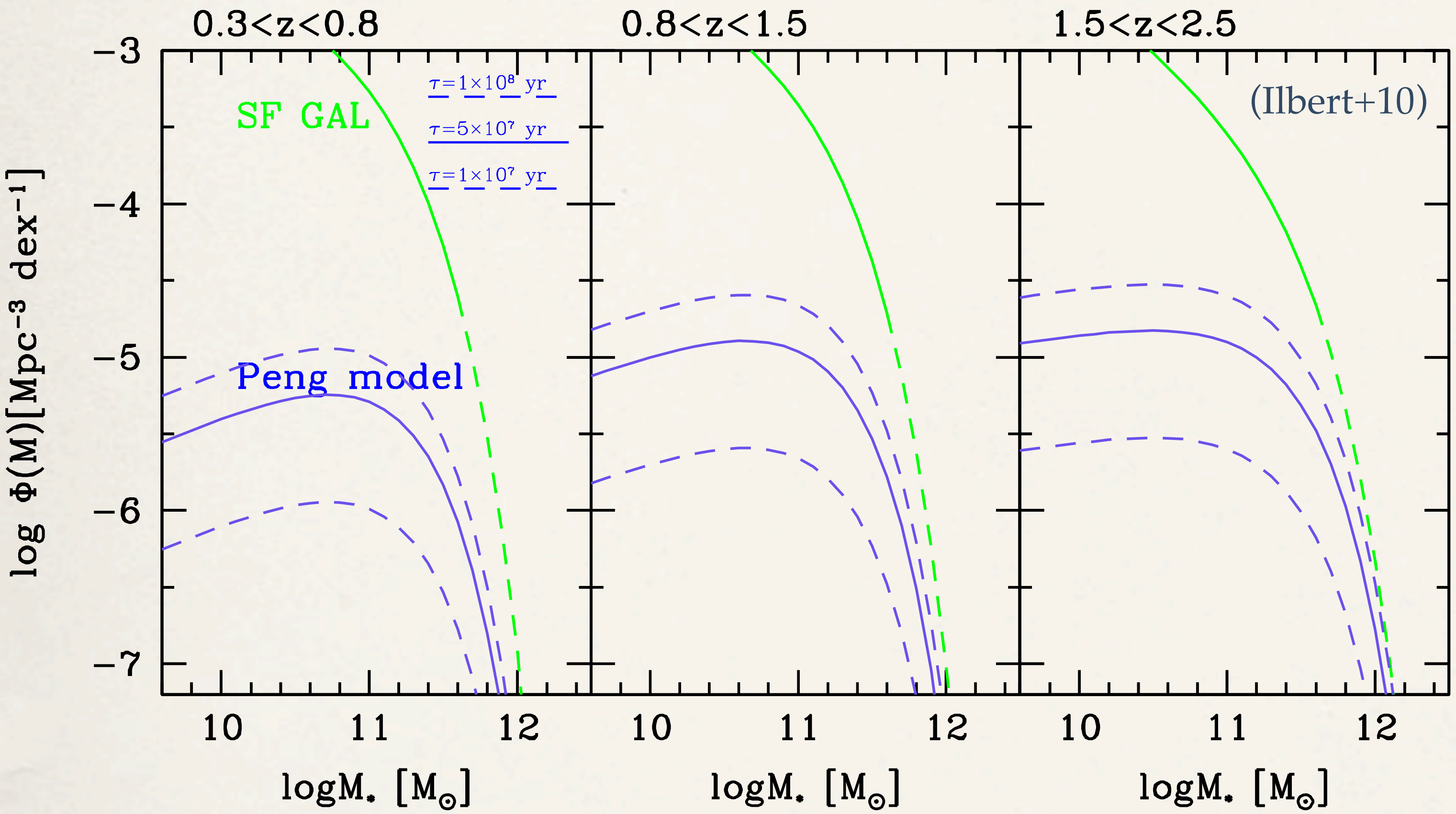
Lilly et al., 2013

with τ_{trans} = 10^6 - 10^7 yr

gas depletion time scale of the outflow

(Maiolino+07, Feruglio+10, Cicone+14)

Mass function of the transient population (Peng et al., 2010)



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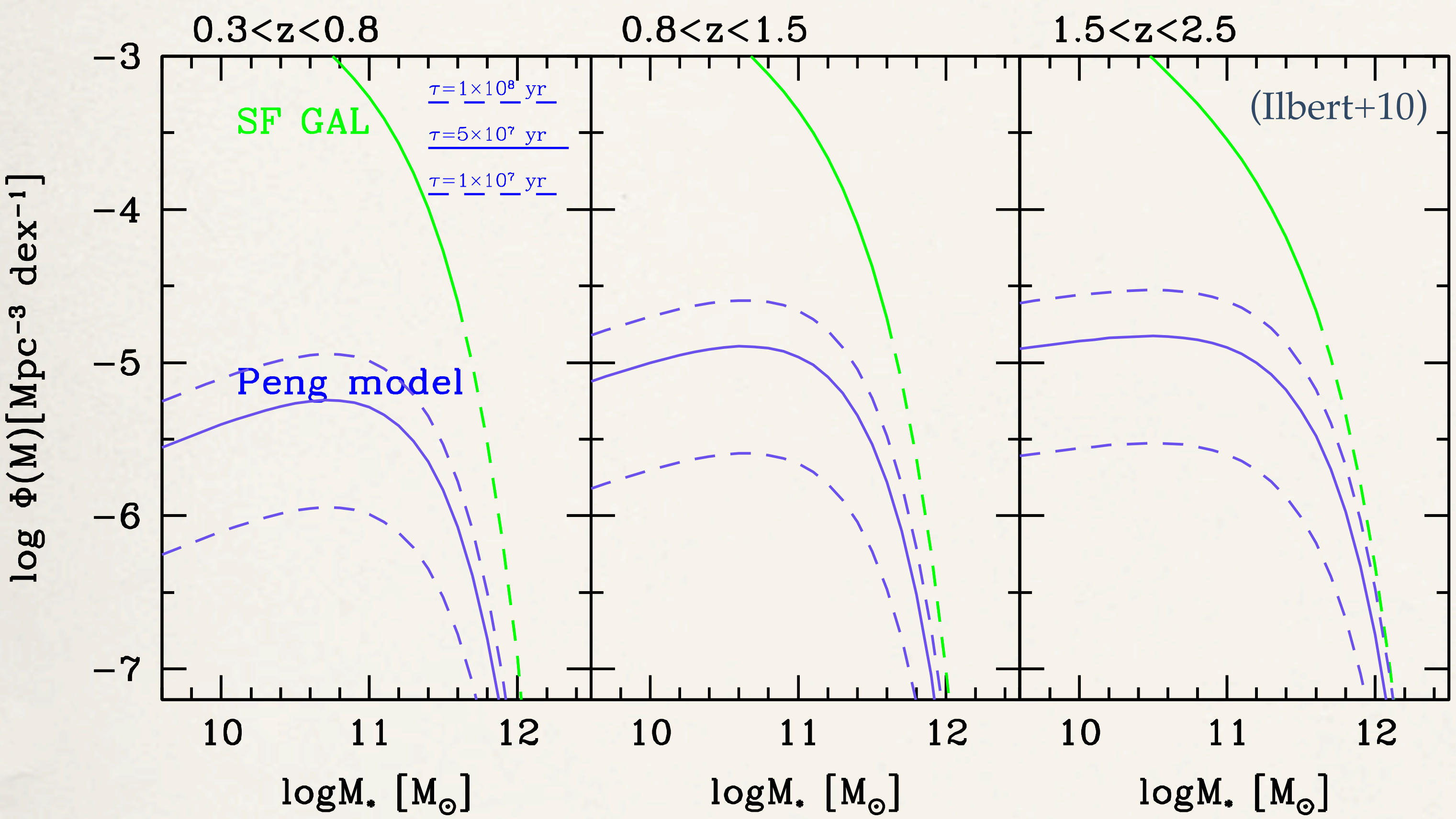

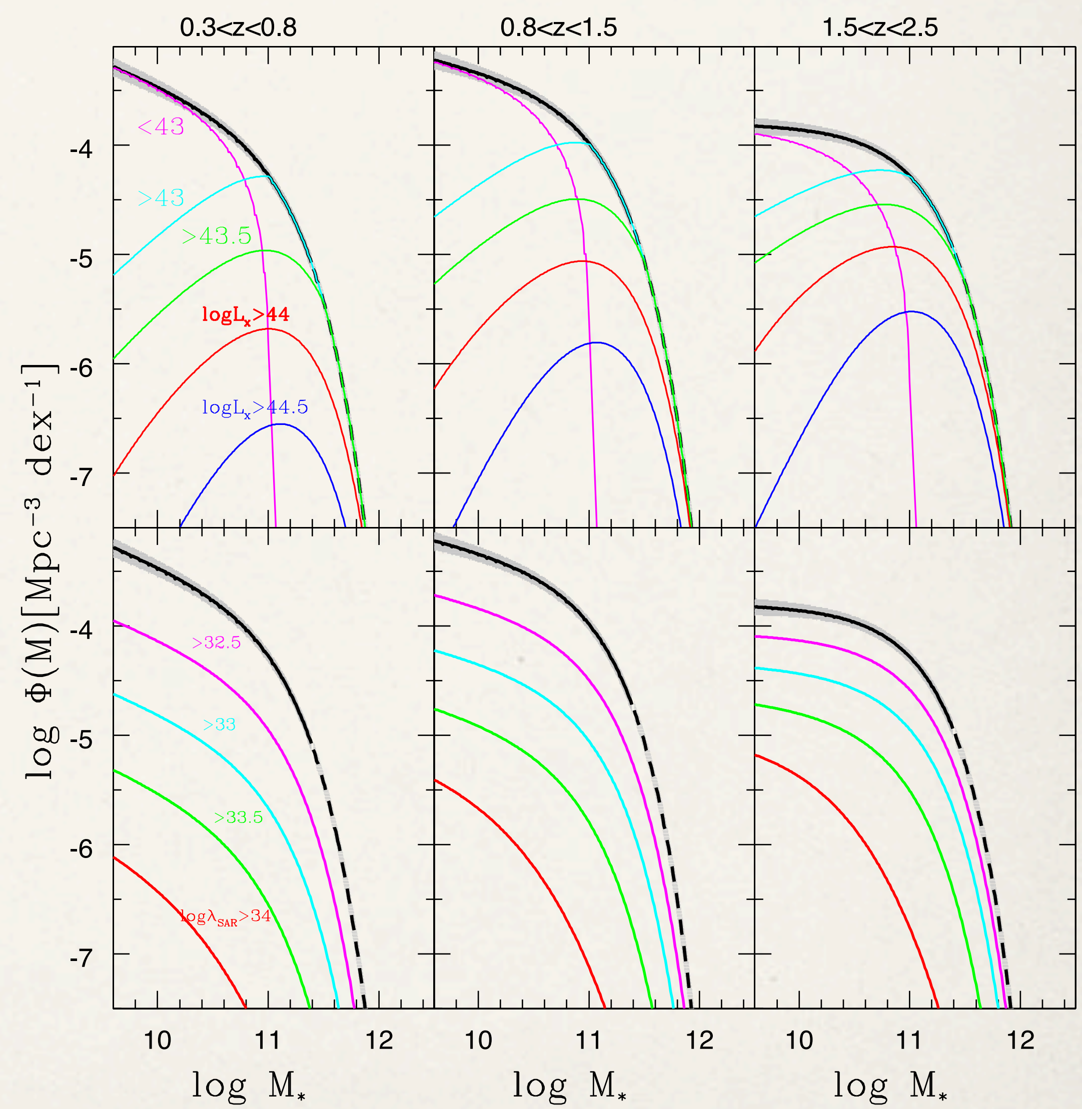

(Bongiorno+16)

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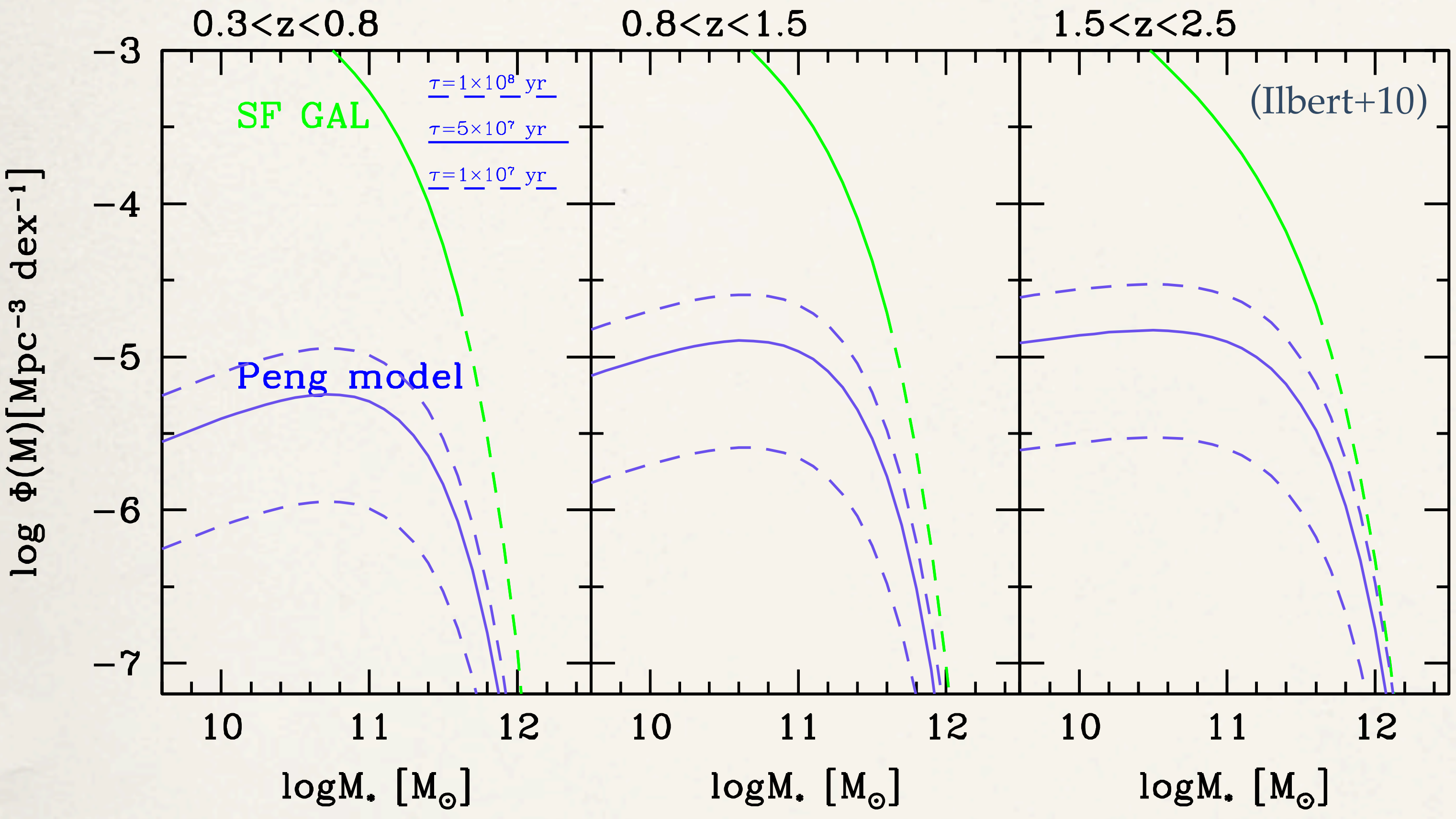
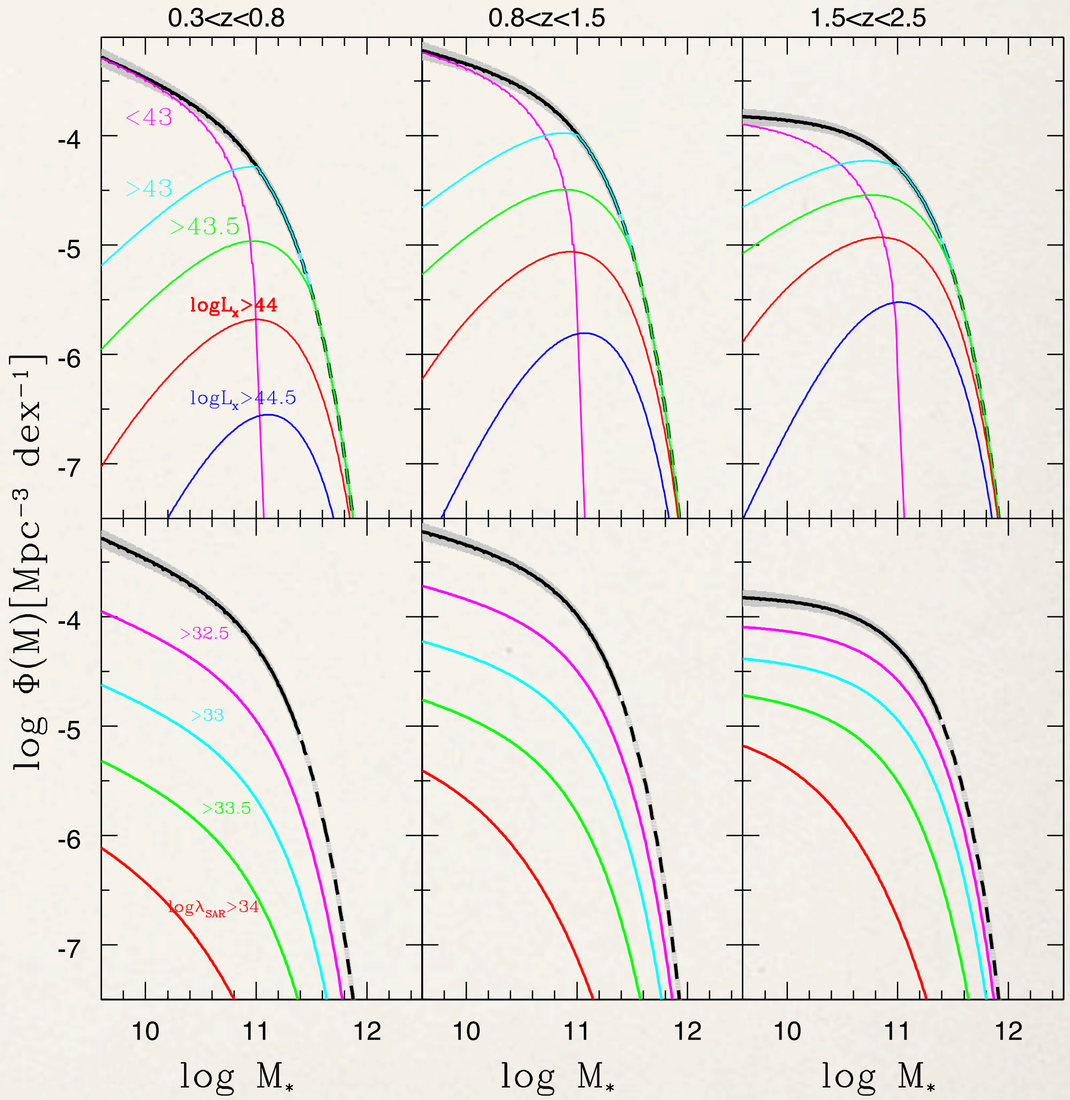
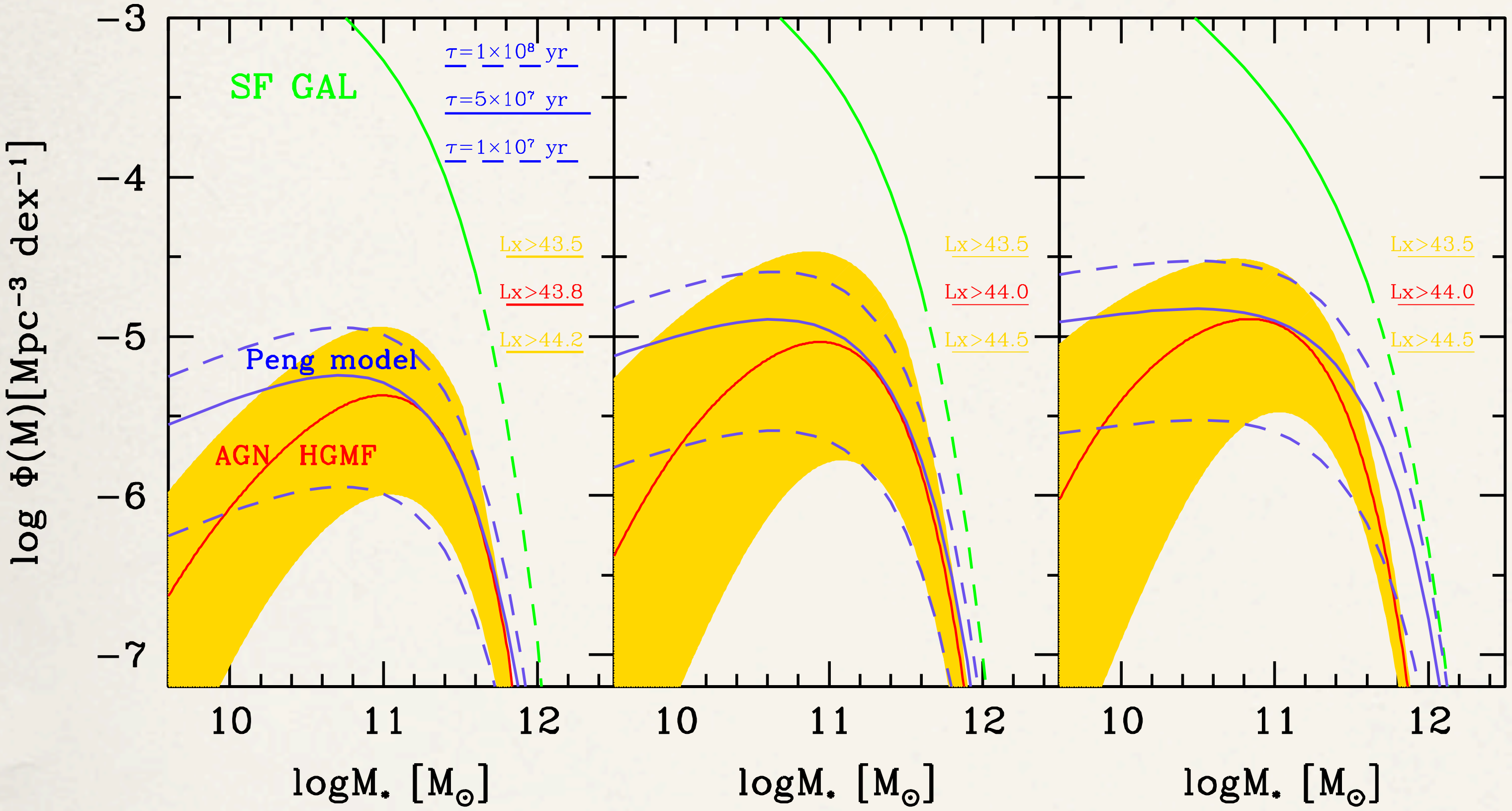
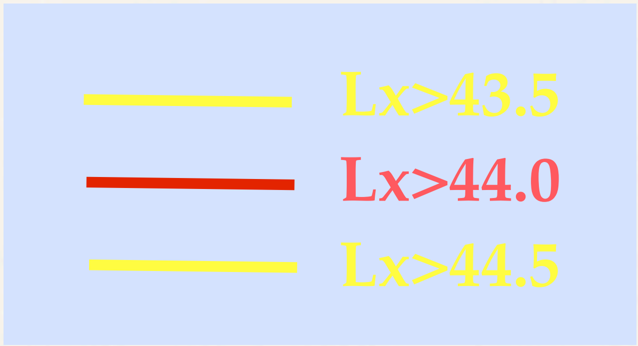




(Bongiorno+16)

Mass function of the transient population





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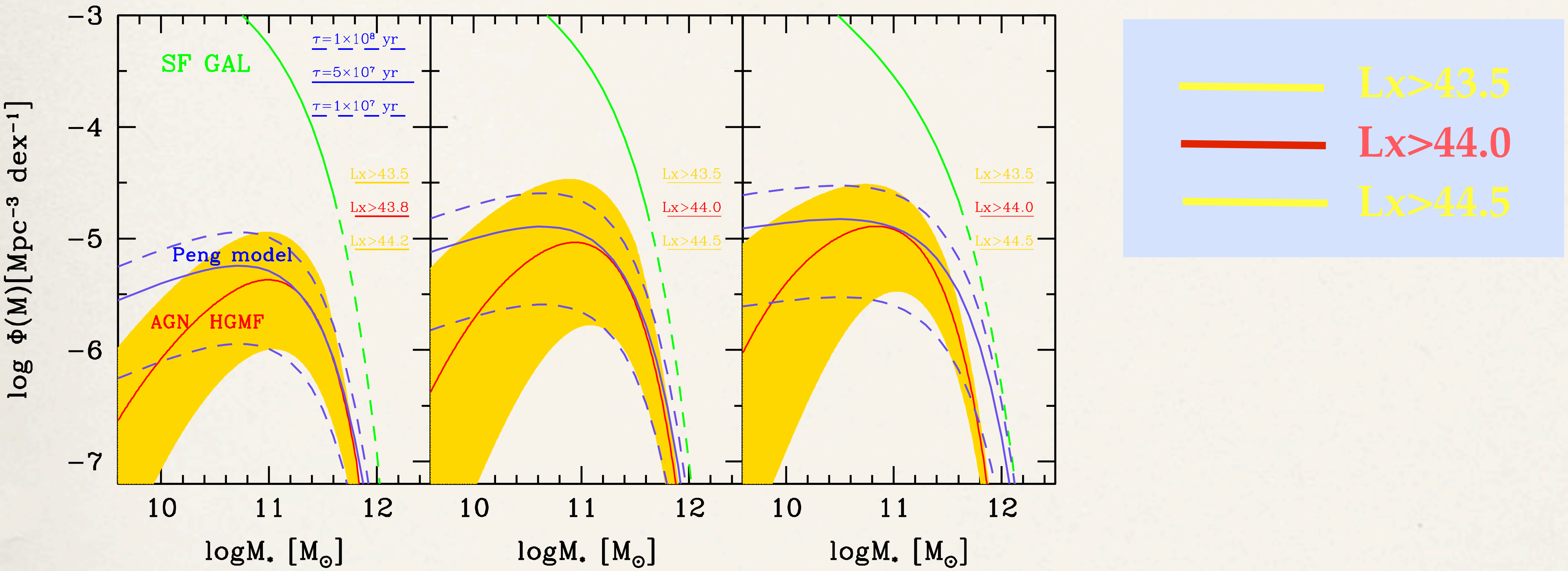
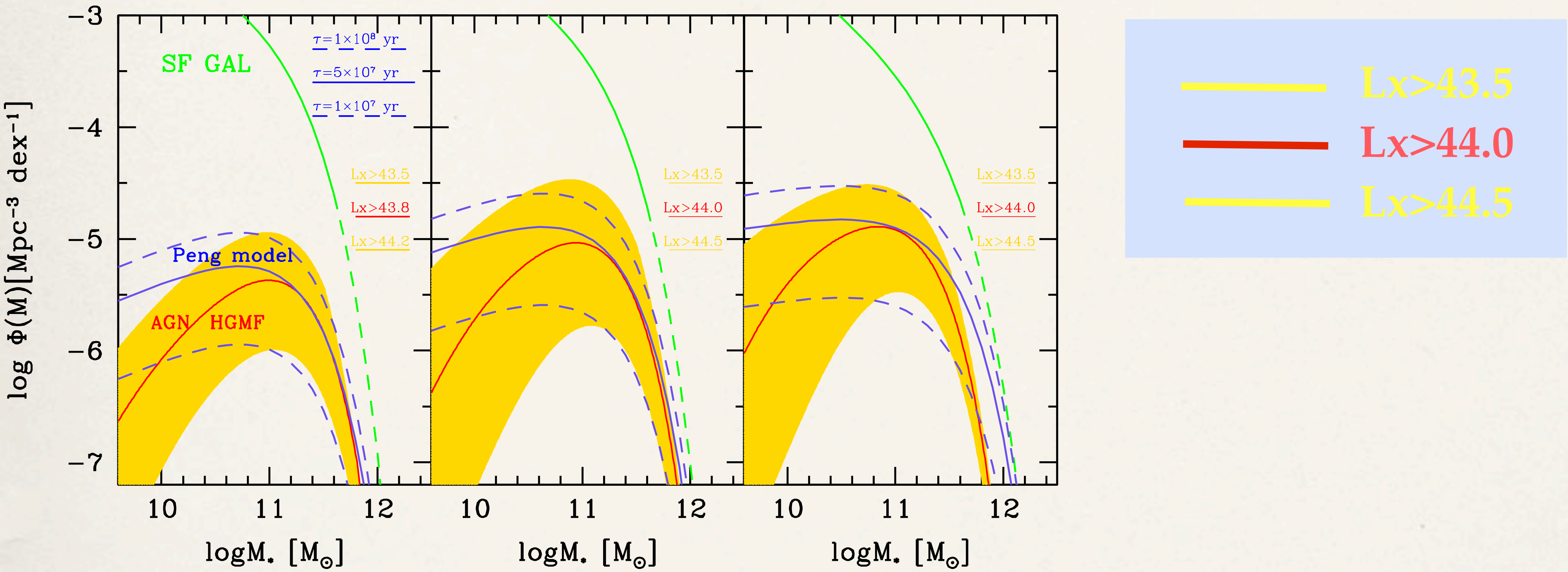


At high Mass, the HGMF of Lx>43.5-44.5 AGN can reproduce well the model prediction for the transition population

(Bongiorno+16)

Mass function of the transient population



AT HIGH MASS, THE HGMF OF LX>43.5-44.5 AGN CAN REPRODUCE WELL THE MODEL PREDICTION FOR THE TRANSITION POPULATION

<u>**IF** AGN driven feedback is responsible for mass-quenching:</u>

- **High L AGN** (log(Lx)>44.0-44.5) are the ones associated to quenching
- It affects only **high Mass** galaxies (log(M/M☉)>11-11.5)

(Bongiorno+16)

Comparison with previous results and model expectation

Feedback from AGN seems to be associated to SF quenching:

a) for high L AGN

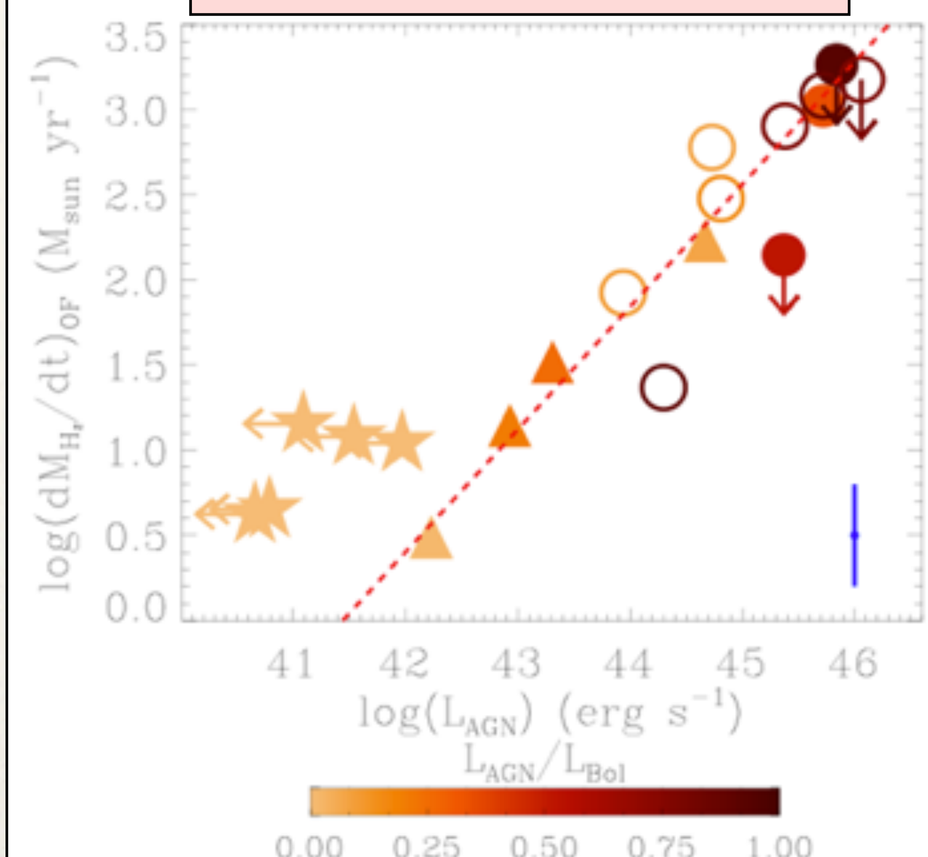
Theoretically:

- ✤ Efficiency of driving energetic outflows increases with AGN luminosity
  (Menci+08,Faucher-Giguere & Quartet2012,Zubovas&King2012)

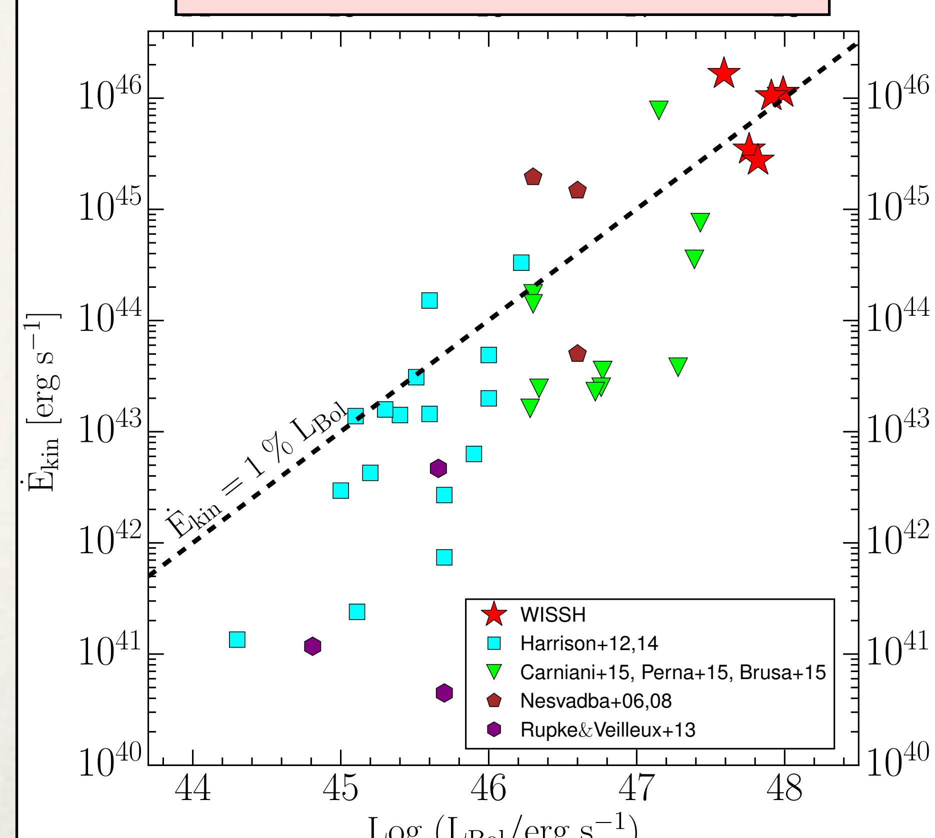
$\dot{M}_{out} \propto L^{1/2}$

Observationally:

kpc-scale *molecular* outflows
(Cicone+14)



kpc-scale *ionized* outflows
(Bischetti+16)

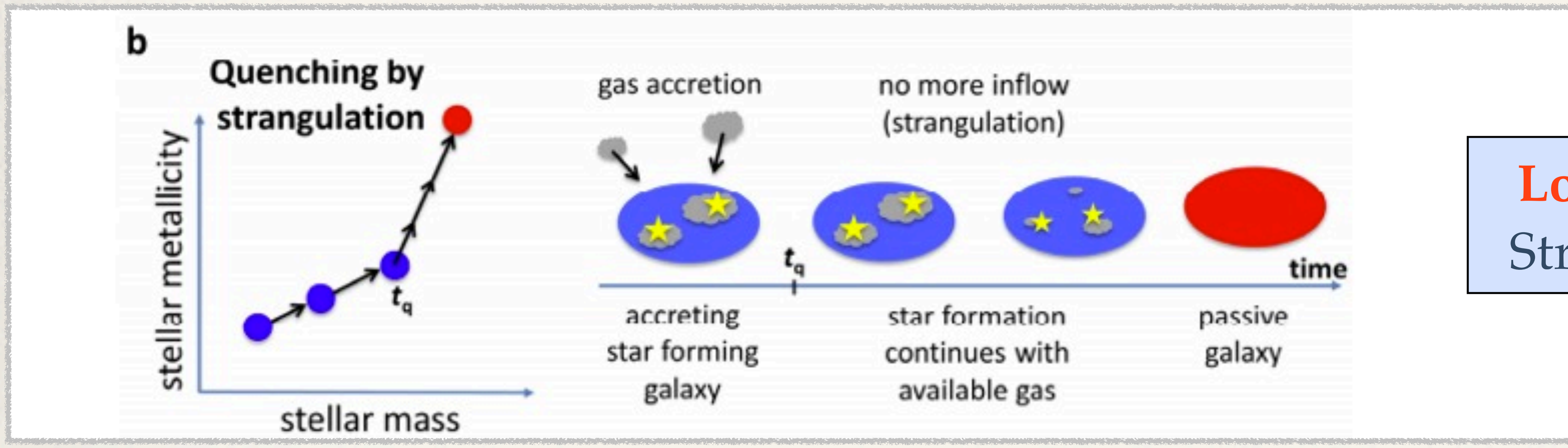


Comparison with previous results and model expectation

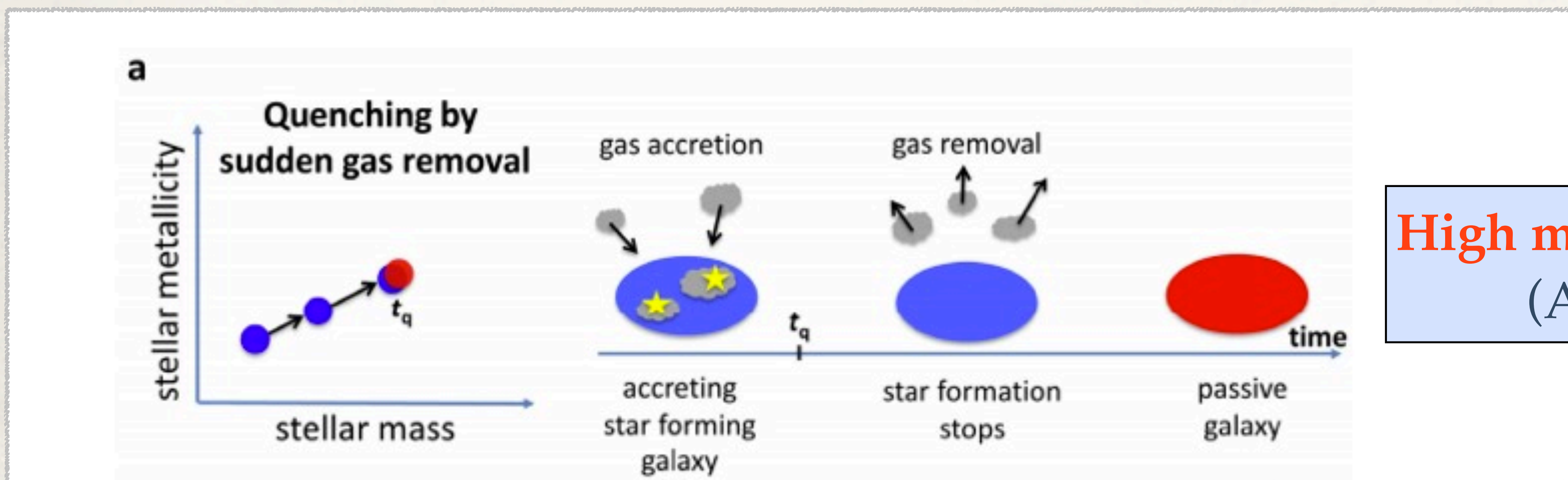
Feedback from AGN seems to be associated to SF quenching:

a) For high L AGN

b) In high Mass galaxies



Low masses: Strangulation



High masses: Gas removal (AGN feedback?)

(Peng et al, 2015 Nature)

Conclusion

✤AGN feedback as possible responsible SF quenching mechanism is **KEY** to fully understand the evolution of galaxies in the Universe

SARDF & HGMF on XMM COSMOS sample

✤ SARDF described by a double PL with the low λ_{SAR} slope flattening with z and the normalization increasing

✤ HGMF described by a Schechter function with the low mass slope flattening with z

✤ AGN-driven feedback is a possible mechanism associated to galaxy quenching

✤ **If** AGN driven feedback is responsible for mass-quenching:

- **High L AGN** (log(Lx)>44.0-44.5) are the ones associated to quenching
- It affects only **high Mass** objects ($\log(M/M_{\odot})$>11-11.5)