Obscured QSOs in the golden epoch of AGN-galaxy evolution

placing objects in the mergers sequence (with NIR and mm observations)

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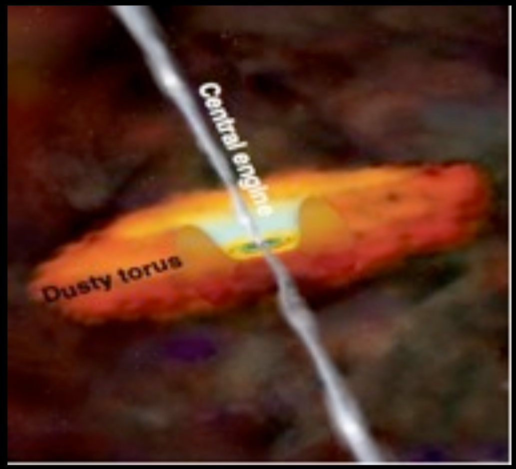
(major) credits: A. Bongiorno, V. Mainieri

Active Galactic Nuclei in a cosmological framework

MAIN ARGUMENTS:



1) AGN trace (accreting) SMBH

SMBH ($M>10^6\ M_\odot$) are powering Active Galactic Nuclei (AGN)

Source of power: accretion of material onto the SMBH through an accretion disc

Active Galactic Nuclei
in a cosmological framework

MAIN ARGUMENTS:

1) AGN trace (accreting) SMBH

2) (non active) SMBH are ubiquitous in nearby galaxies

Chandra, HST, VLA/VLBI surveys of Palomar sample, AMUSE-VIRGO
(Elvis & Keel '84; Ho, Filippenko, Nagar, Wilson, Gallo etc. 1997-2007)

→ AGN transient phase

Active Galactic Nuclei in a cosmological framework

MAIN ARGUMENTS:

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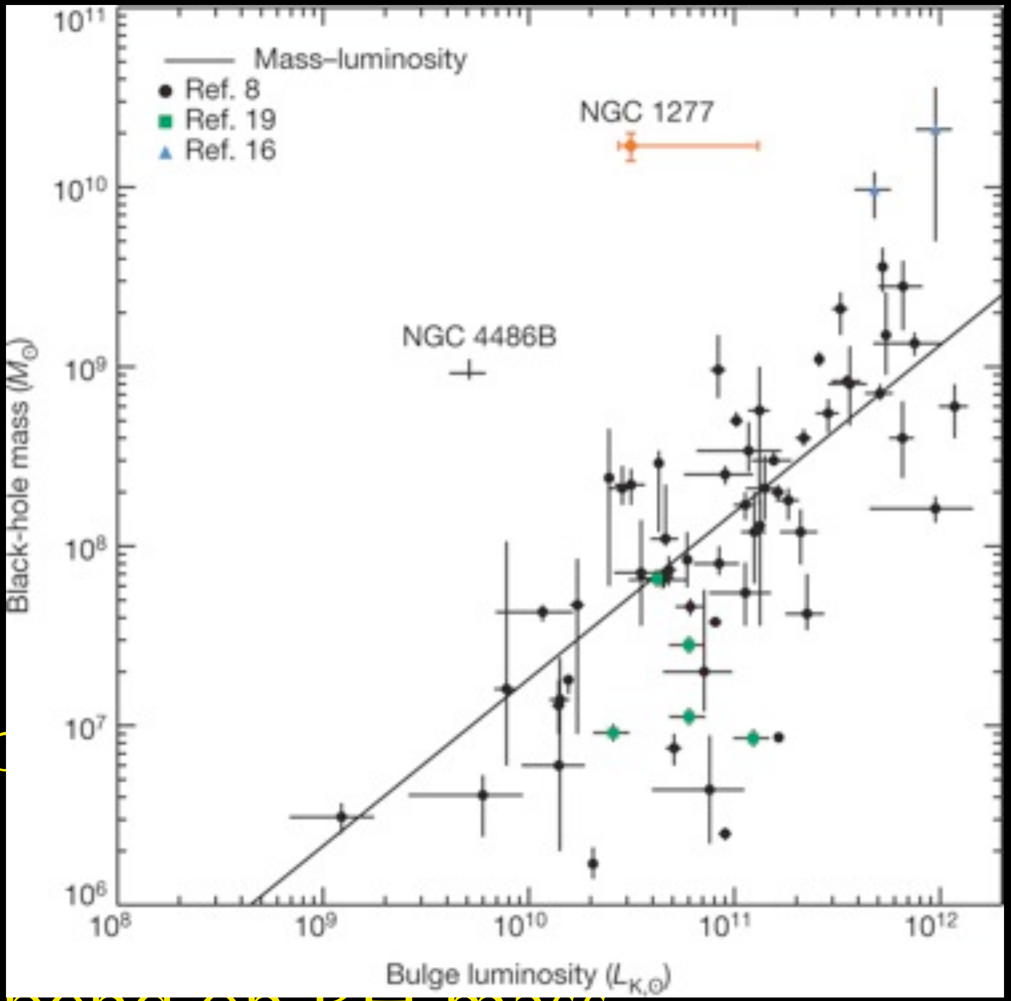
2) (non active) SMBH are ubiquitous in nearby galaxies

3) Large scale galaxies properties strongly depend on BH mass

tight correlation between M_{BH} and bulge properties

(e.g. Magorrian+1998, Ferrarese & Merritt 2000, Gebhardt et al. 2000, Marconi & Hunt 2003, Haring & Rix 2004, Greene et al. 2007, Gultekin et al. 2009, van de Boesch et al. 2012)

Active Galactic Nuclei in a cosmological framework



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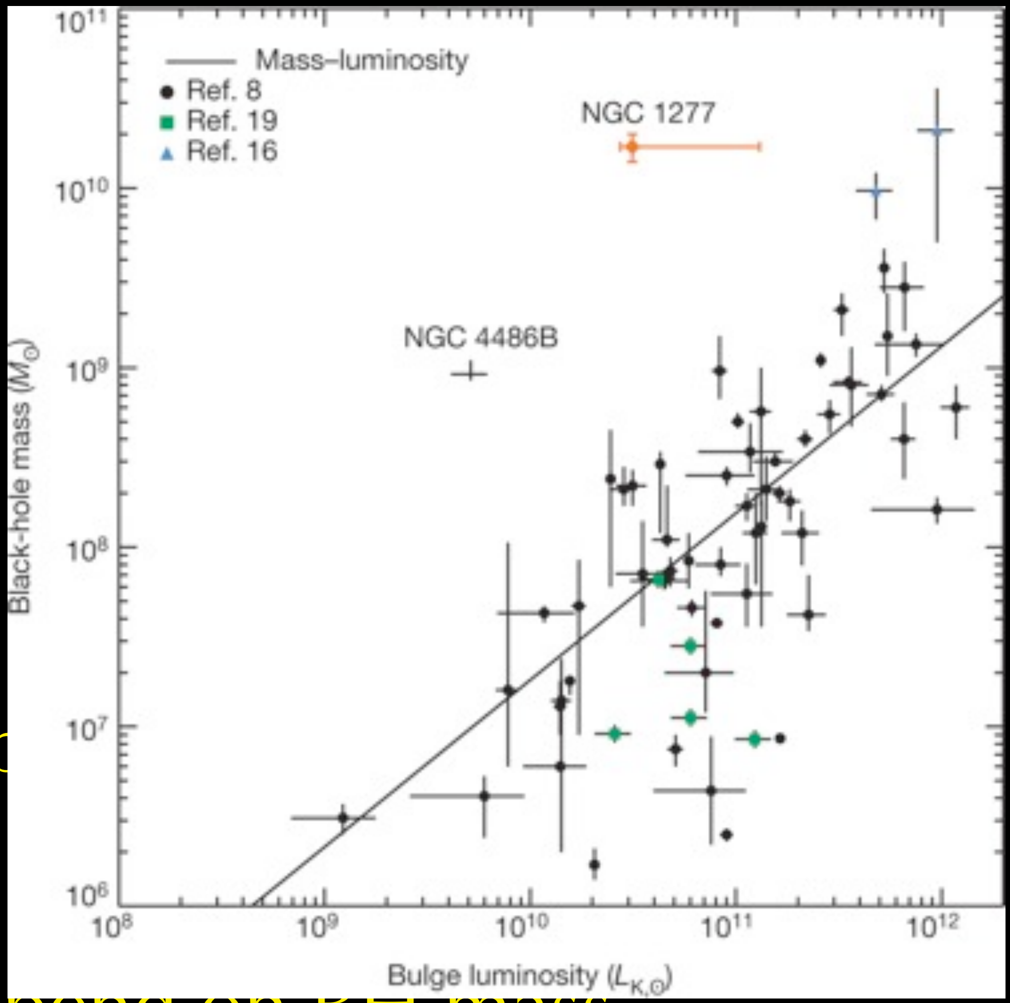

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AGN play a key role in galaxy evolution: “Feedback”

AGN-galaxy coevolution "paths"

MERGERS SCENARIO:

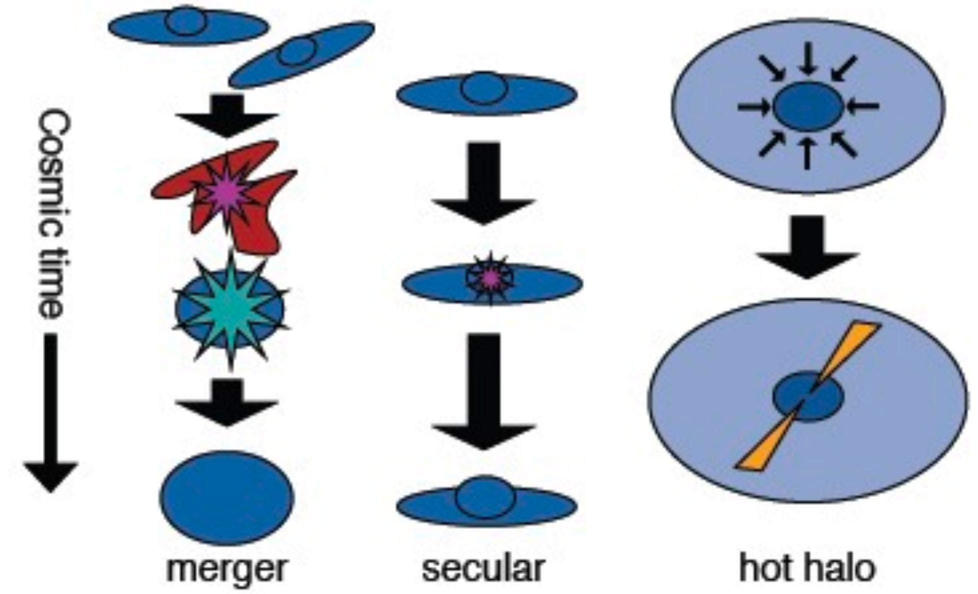
(last decade paradigm)

Major mergers can **trigger SF and BH activity** (Silk & Rees 1998, Granato et al. 2004, Di Matteo et al. 2005, Croton et al. 2006, Fontanot et al. 2006, De Lucia et al. 2006, Sijacki et al. 2007, Menci et al. 2008, Hopkins et al. 2008, Marulli et al. 2009)

strong correlation between M_{BH} and bulge properties (e.g. Ferrarese & Merritt 2000, Gebhardt et al. 2000, Marconi & Hunt 2003, Haring & Rix 2004, Greene et al. 2007, Gultekin et al. 2009)

QSO-ULIRGS connection (e.g. Sanders et al. 1988,)

Alexander & Hickox 2012



SECULAR SCENARIO:

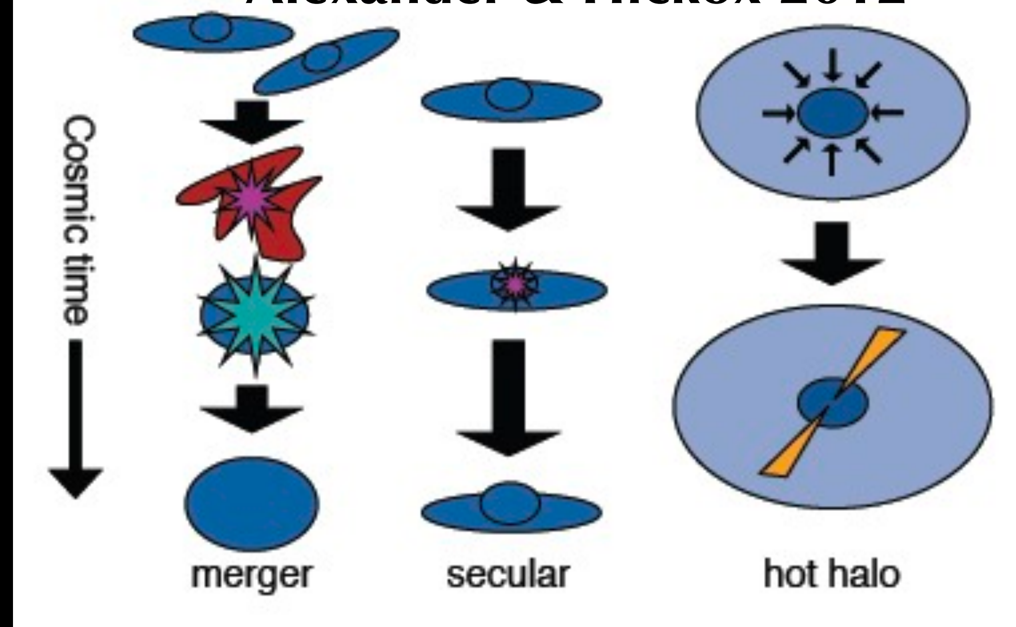
(this decade novelty)

(weak) activity driven stochastically by local processes (inflow, disks/bars instabilities; Croton+2006, Ciotti&Ostriker 2007, Cen 2011, Bournaud+2011, Di Matteo+2011)

no correlation between M_{BH} and disk or pseudobulge properties (Kormendy et al. 2011; see also Graham et al. 2010)

A population of galaxies evolved without mergers does clearly exist (**disks are observed at z~2**; e.g. Genzel +2006, 2008) also in AGN hosts (Cisternas+2011, Kocevski +2012)

AGN-galaxy coevolution "paths"



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no correlation between M

does clearly exist (**disks are observed at z~2**; e.g. Genzel +2006, 2008) also in AGN hosts (Cisternas+2011, Kocevski +2012)

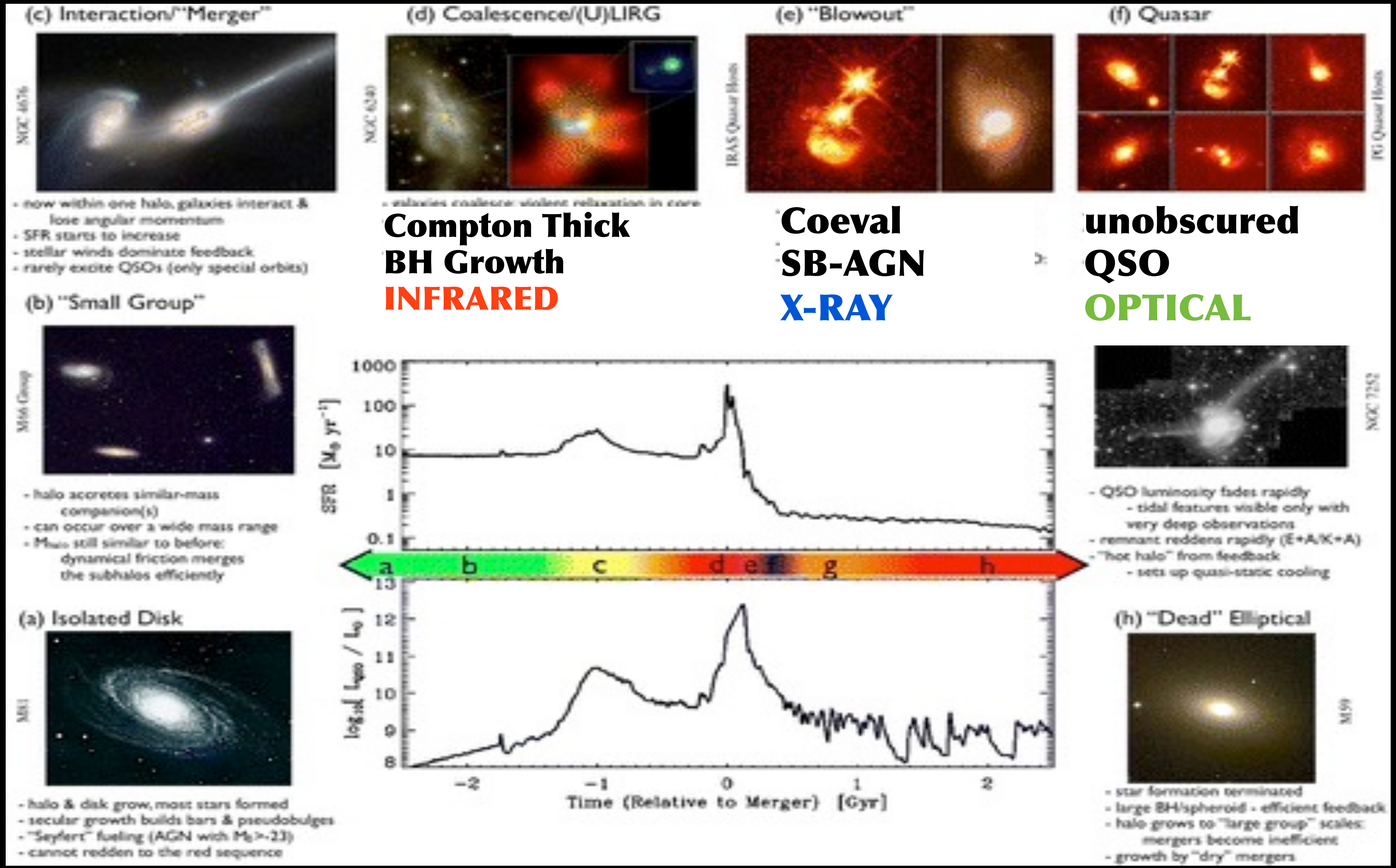
Luminosity dependence?

NEED AREA

NEED RESOLUTION

mergers scenario

Hopkins et al. 2008



MERGERS MODEL IMPLICATIONS:

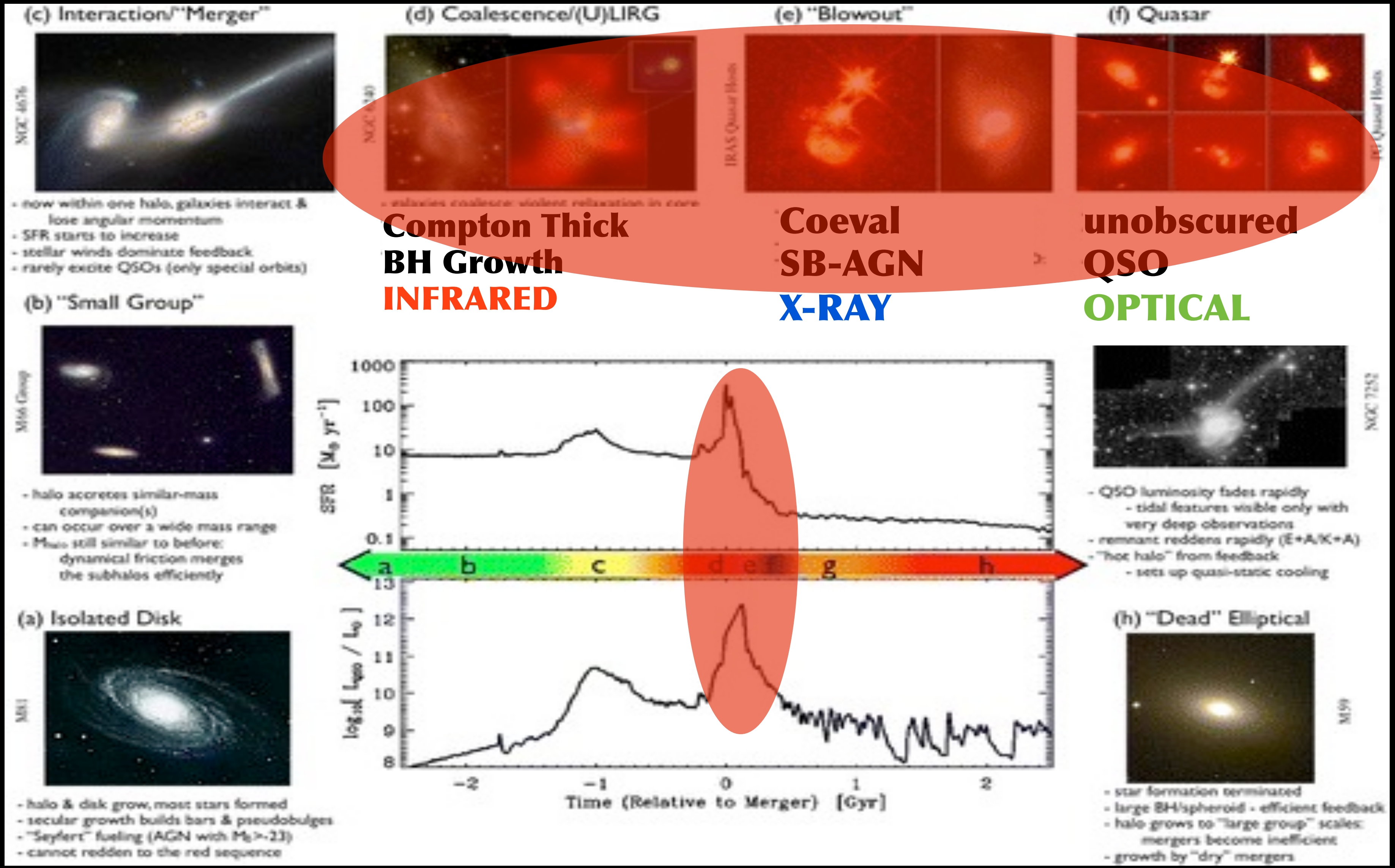
1) obscured AGN: “time” critical

2) BH growth and SF “**simultaneous**”

3) feedback (!)

mergers scenario

Hopkins et al. 2008



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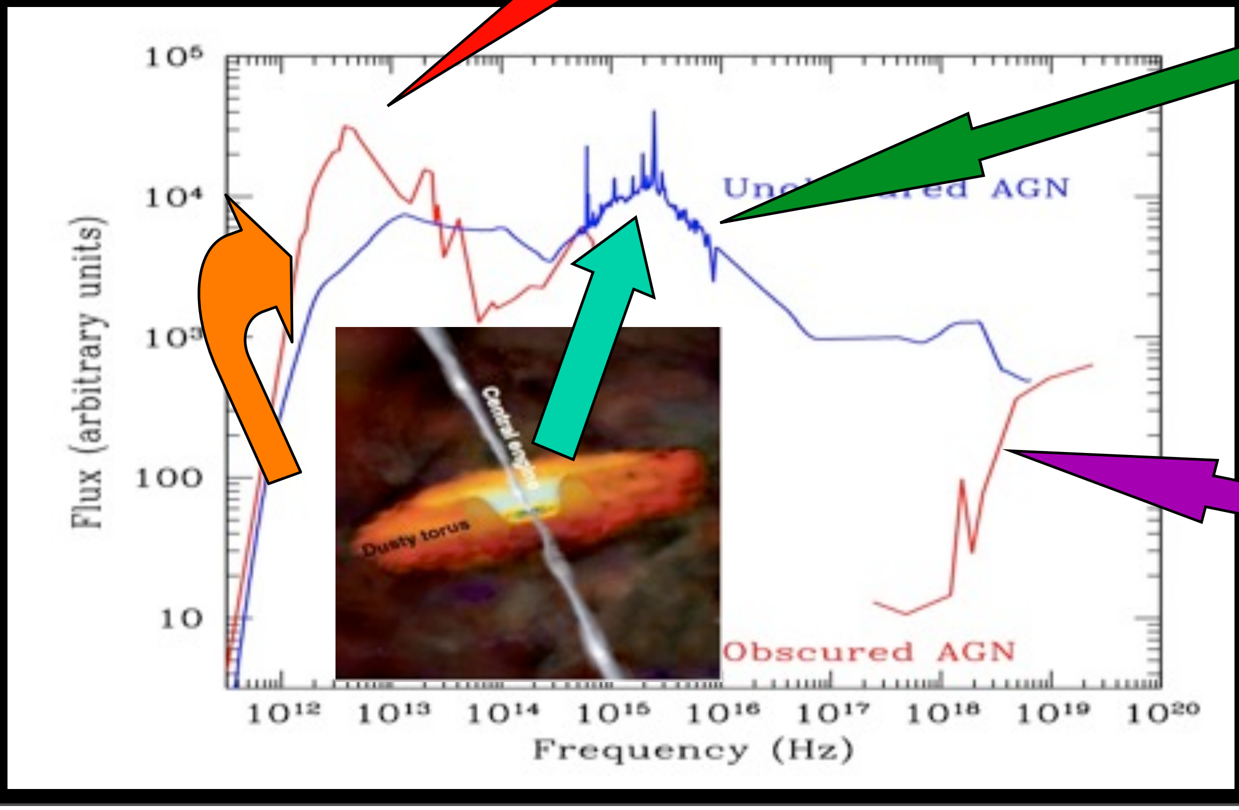
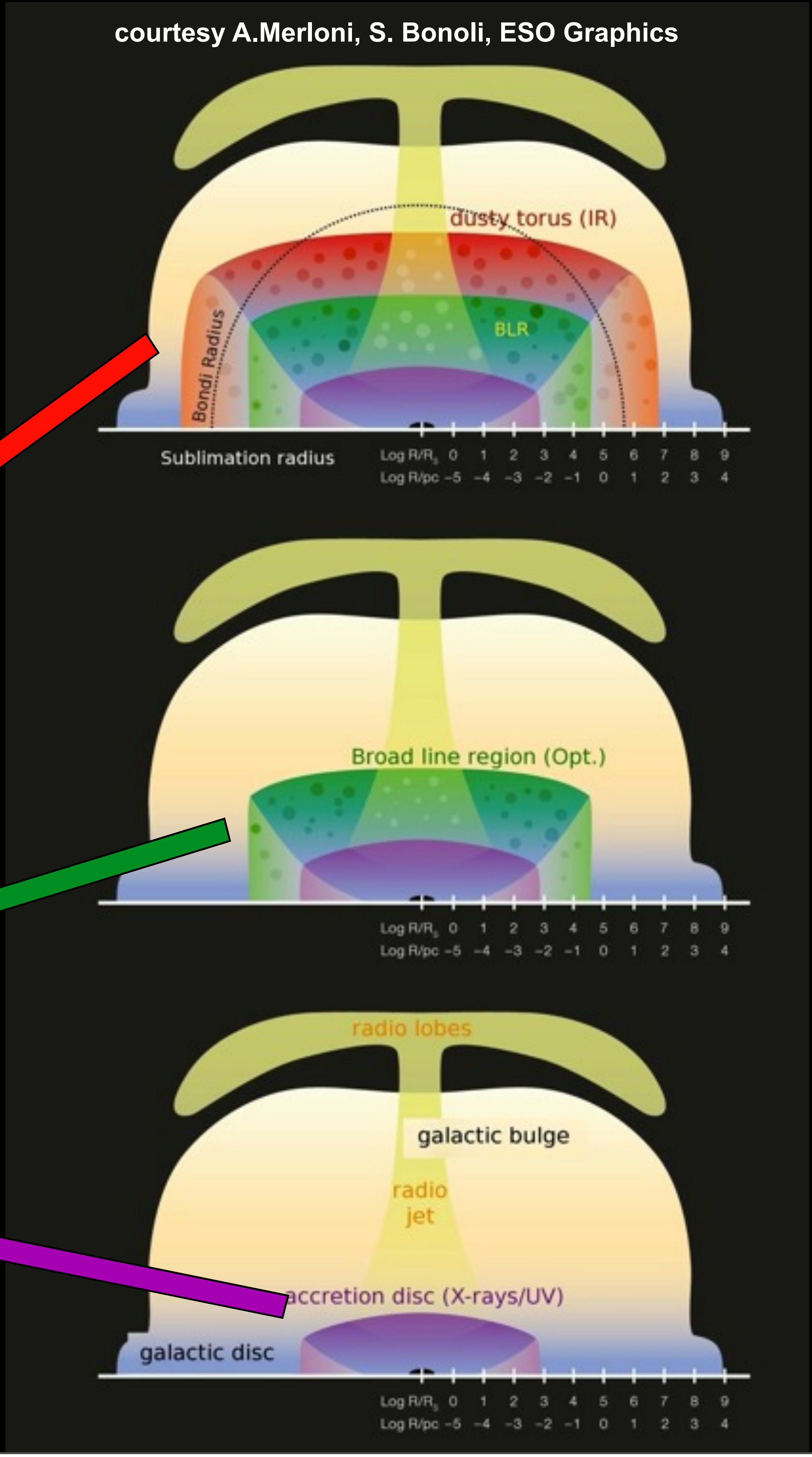
INTERMEZZO (1)
AGN emission

AGN emission is observed over the entire electromagnetic spectrum

Different wavelengths sample different **emission processes** and **emission regions**

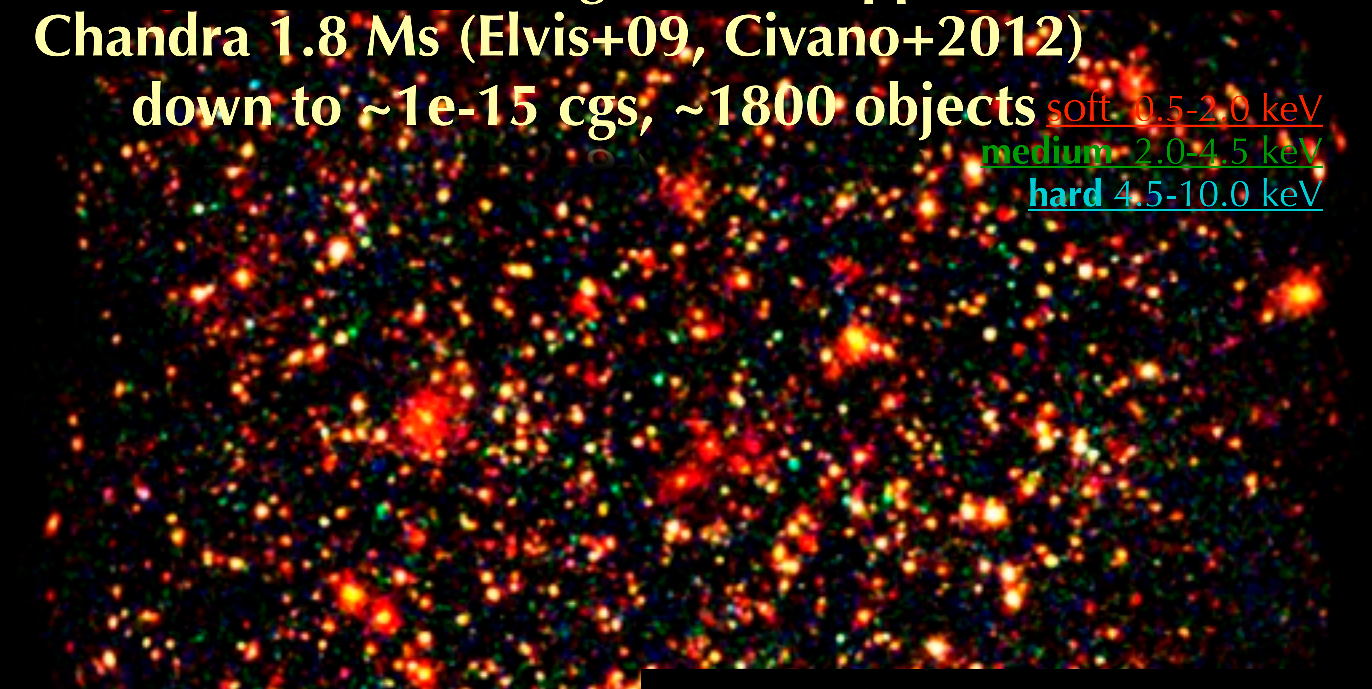
X-ray emission sample the innermost regions (<10^{-2} pc, <1000 R_S)





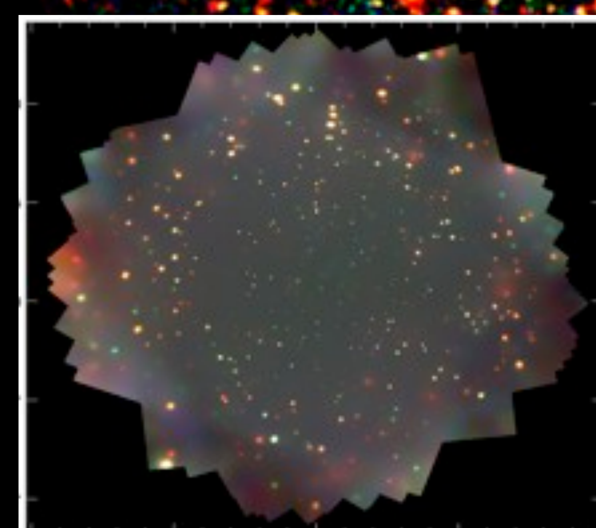
INTERMEZZO (2)
Tools:
X-ray surveys

COSMOS field, 2 deg² (Scoville+07)
XMM 1.55 Ms (Hasinger+07, Cappelluti+09, Brusa+10)
Chandra 1.8 Ms (Elvis+09, Civano+2012)
down to ~1e-15 cgs, ~1800 objects



most complete (modulo Compton Thick sources - “known” missing)

least contaminated (normal galaxies and stars emerge only in deepest exposures)



CDFS Chandra 1-2-4Ms
XMM 3 Ms
~0.1 deg2, ~4e-17 cgs
300-750 objects
(Giacconi+2002, Alexander +2003, Luo+ 2008,10, Xue +2011, Comastri+2011, Ranalli+2013)

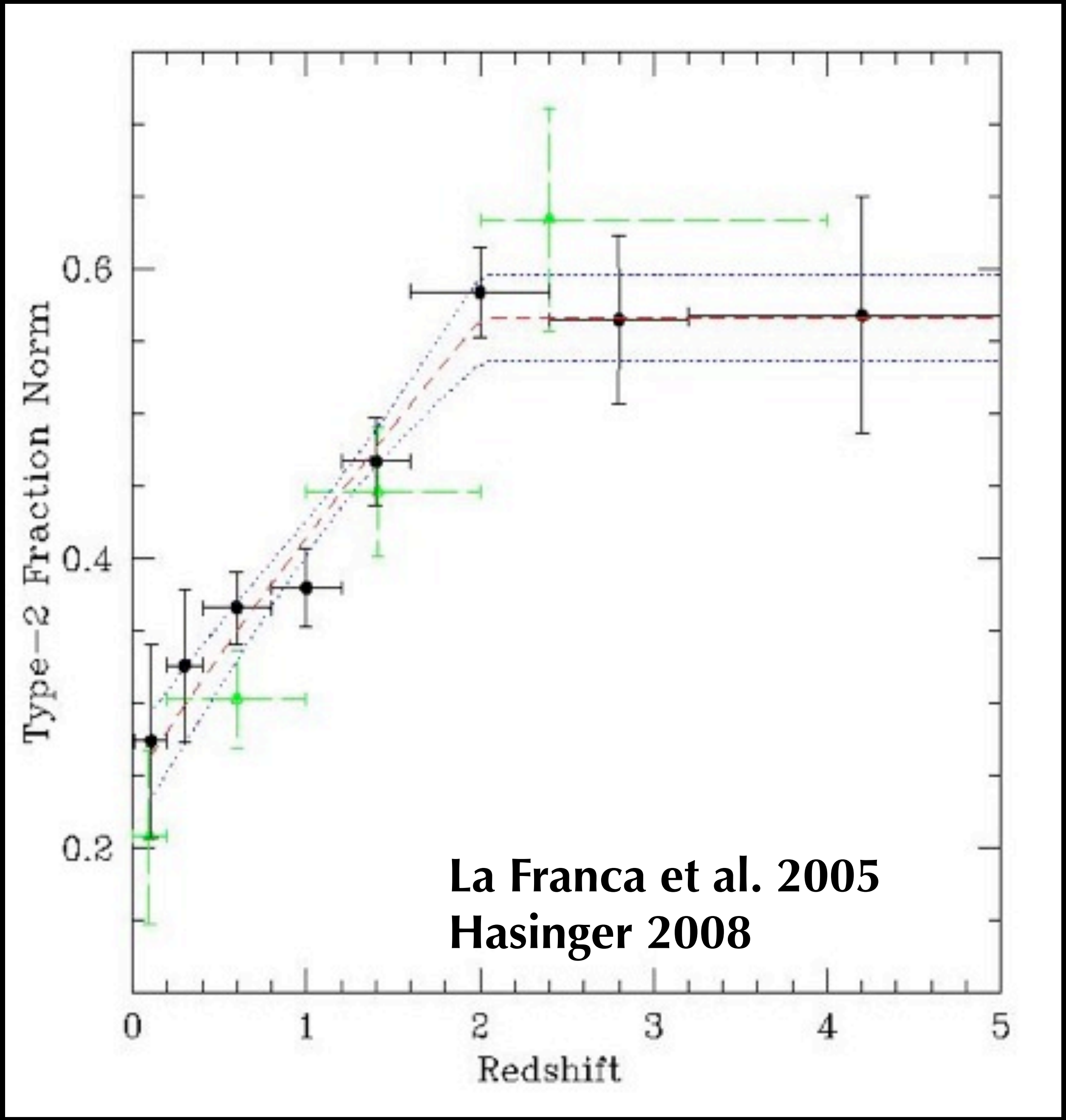
Multiwavelength coverage to assure identification, redshift determination, SED studies, host galaxy properties, and alternative AGN selection (e.g. Compton Thick census)

Ony two among the many (~40) XMM & Chandra surveys in russian-doll style

All wavelengths, very deep coverage available

Thursday, February 21, 2013

1) Obscured fraction as a function of z



Type 2 AGN fraction is higher at high-z ....

higher-z, more cold gas available, more obscured

Detailed studies of z>3 samples also reveal high fraction (>50%) of obscured objects (e.g. Fiore et al. 2012, Vito et al. 2013)

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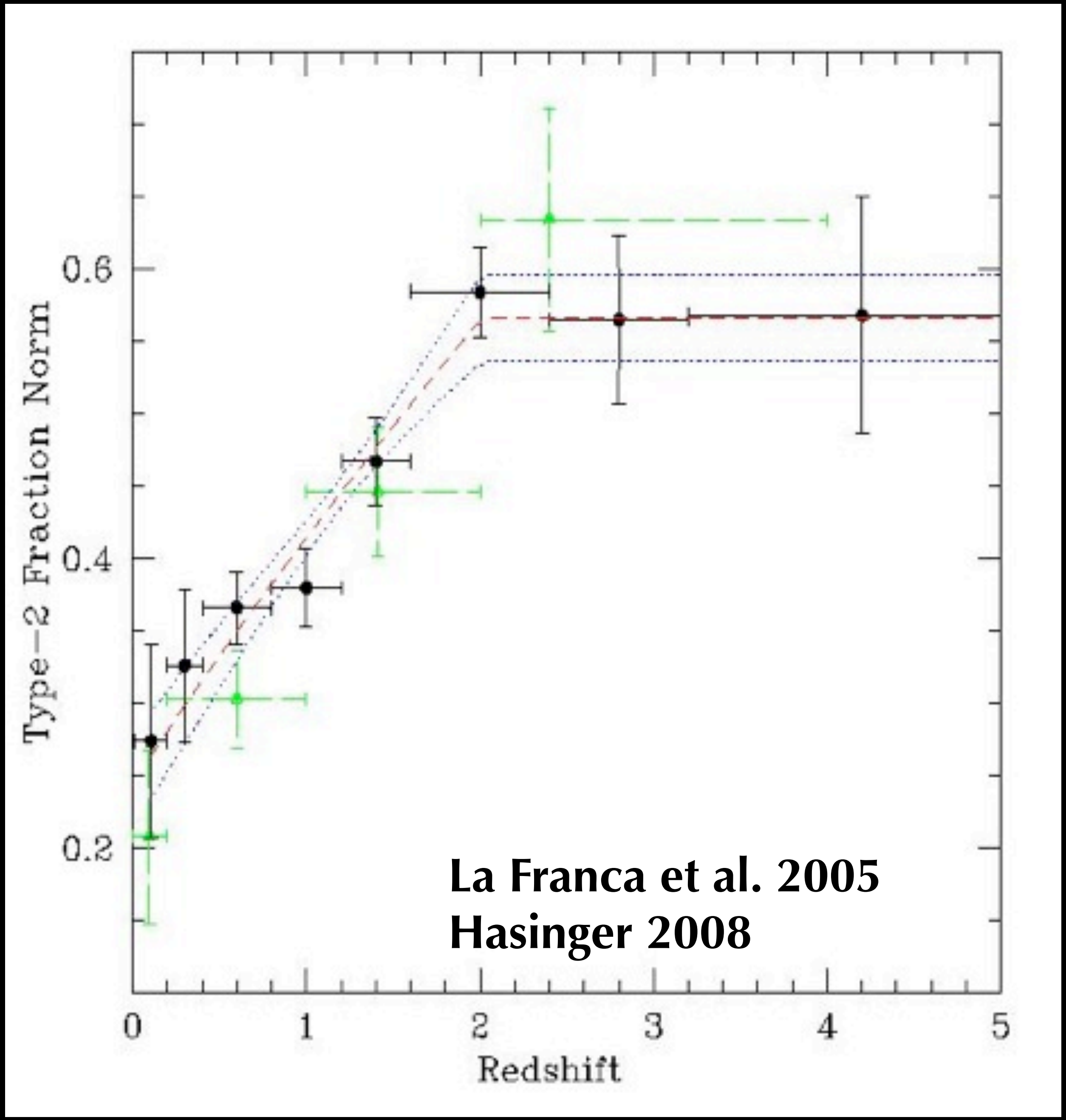

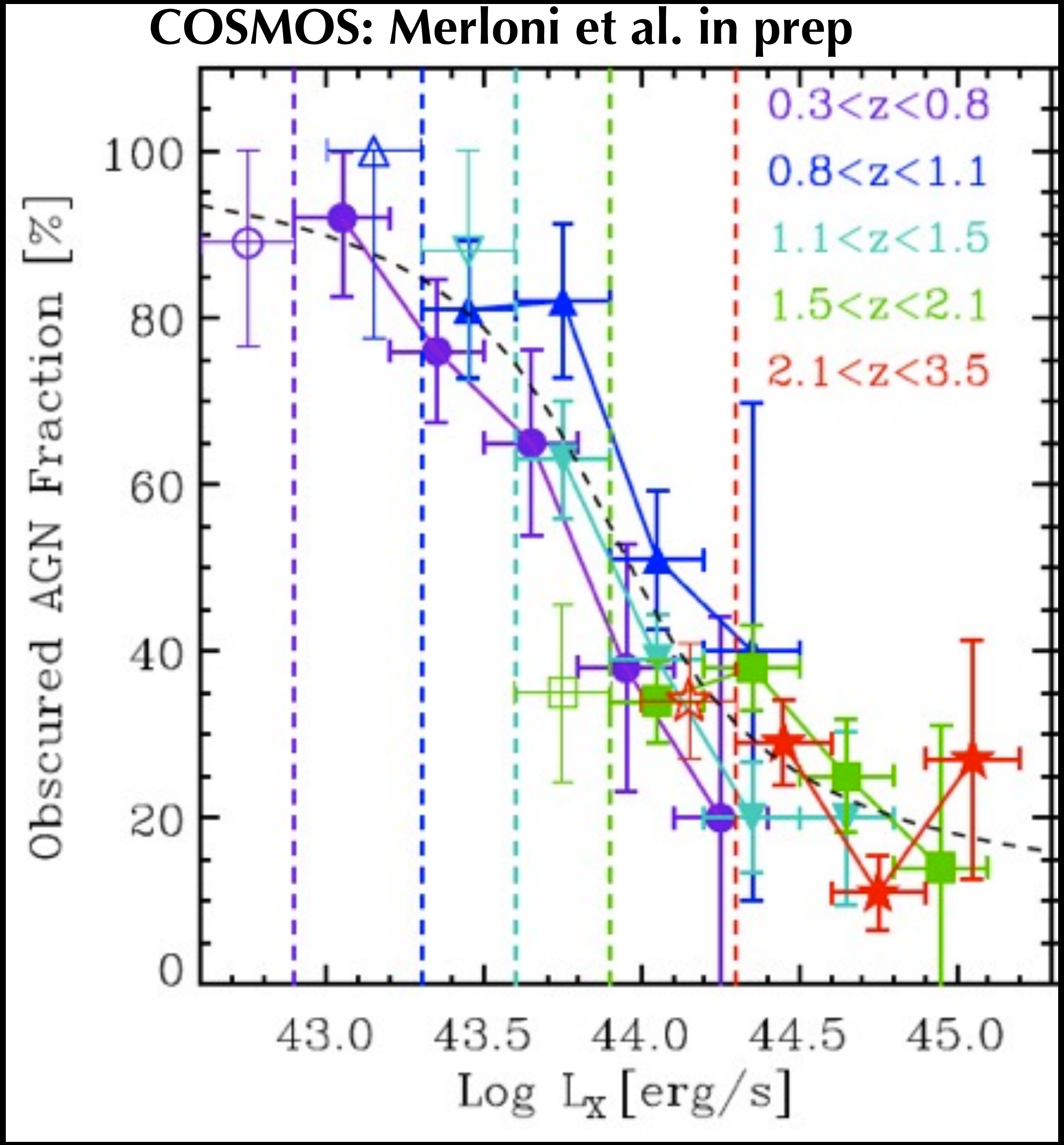

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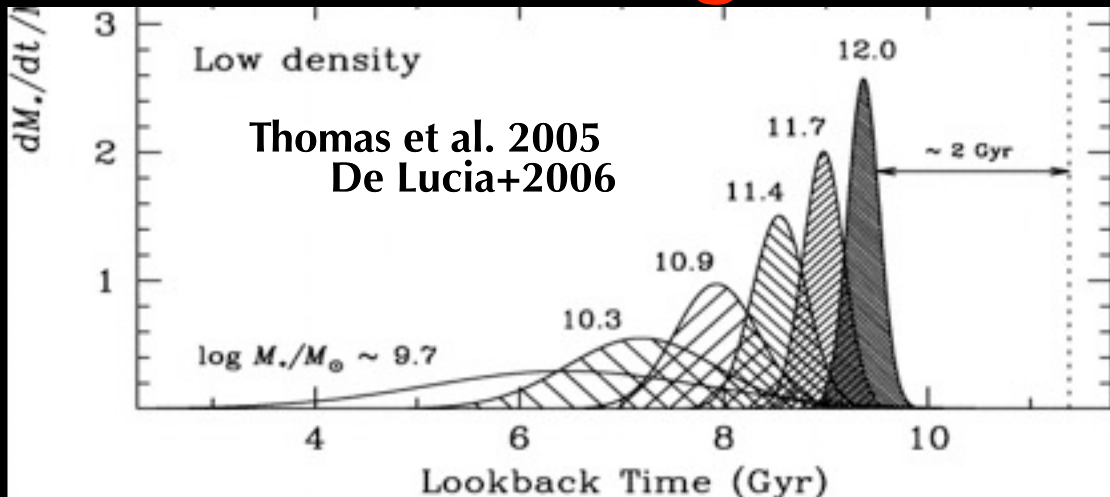
... or not ? Result still very debated after ~10 years

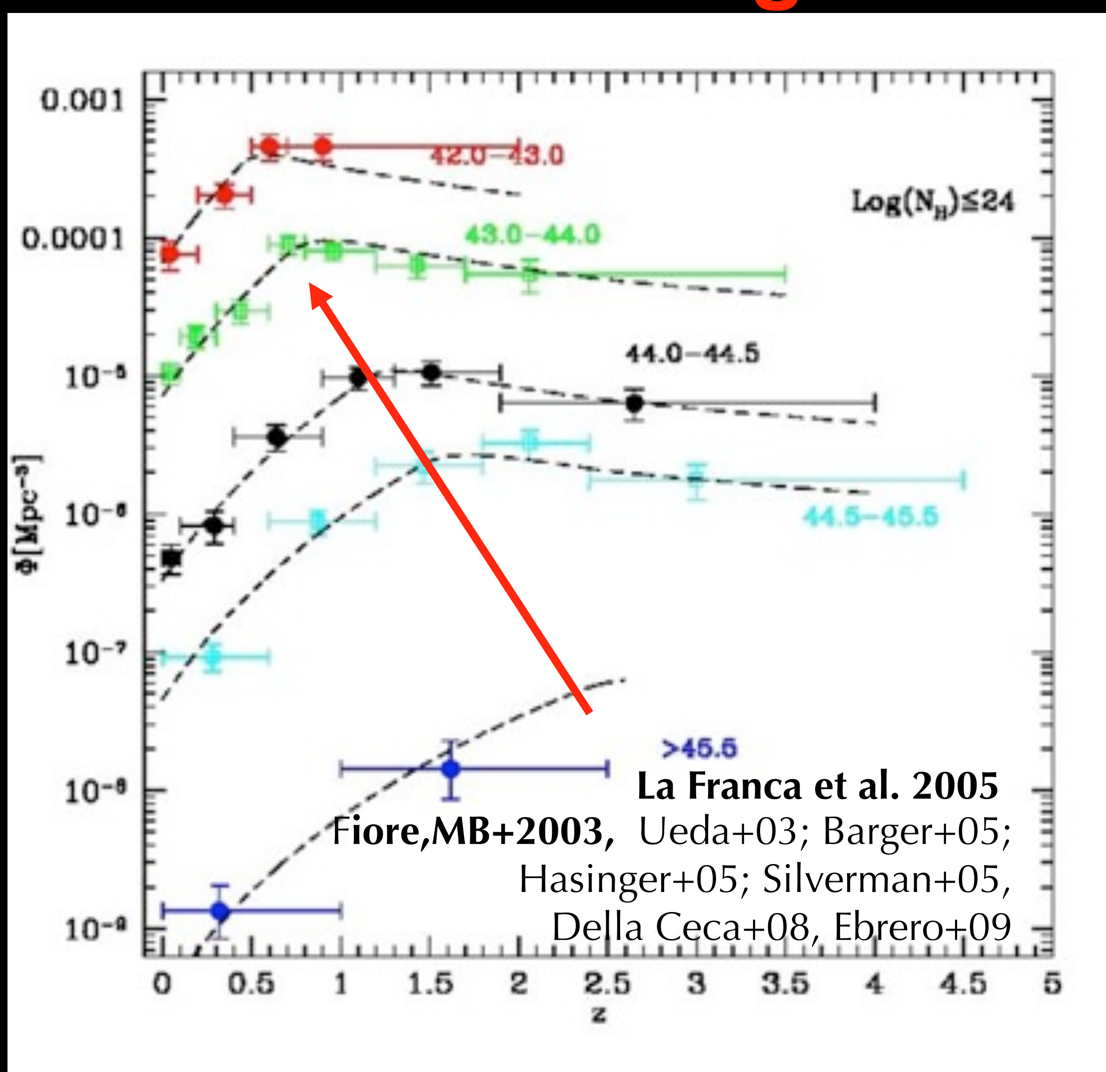
issues of classifications (X-ray/optical), selection (hard/soft), NH determination, Lx etc.

2) Co-eval SF and accretion Downsizing

SF downsizing



AGN downsizing



Cosmic "downsizing" : the larger the faster (Cowie et al. 1996):

".. galaxy formation took place in "downsizing", with more massive galaxies forming at higher redshift.."

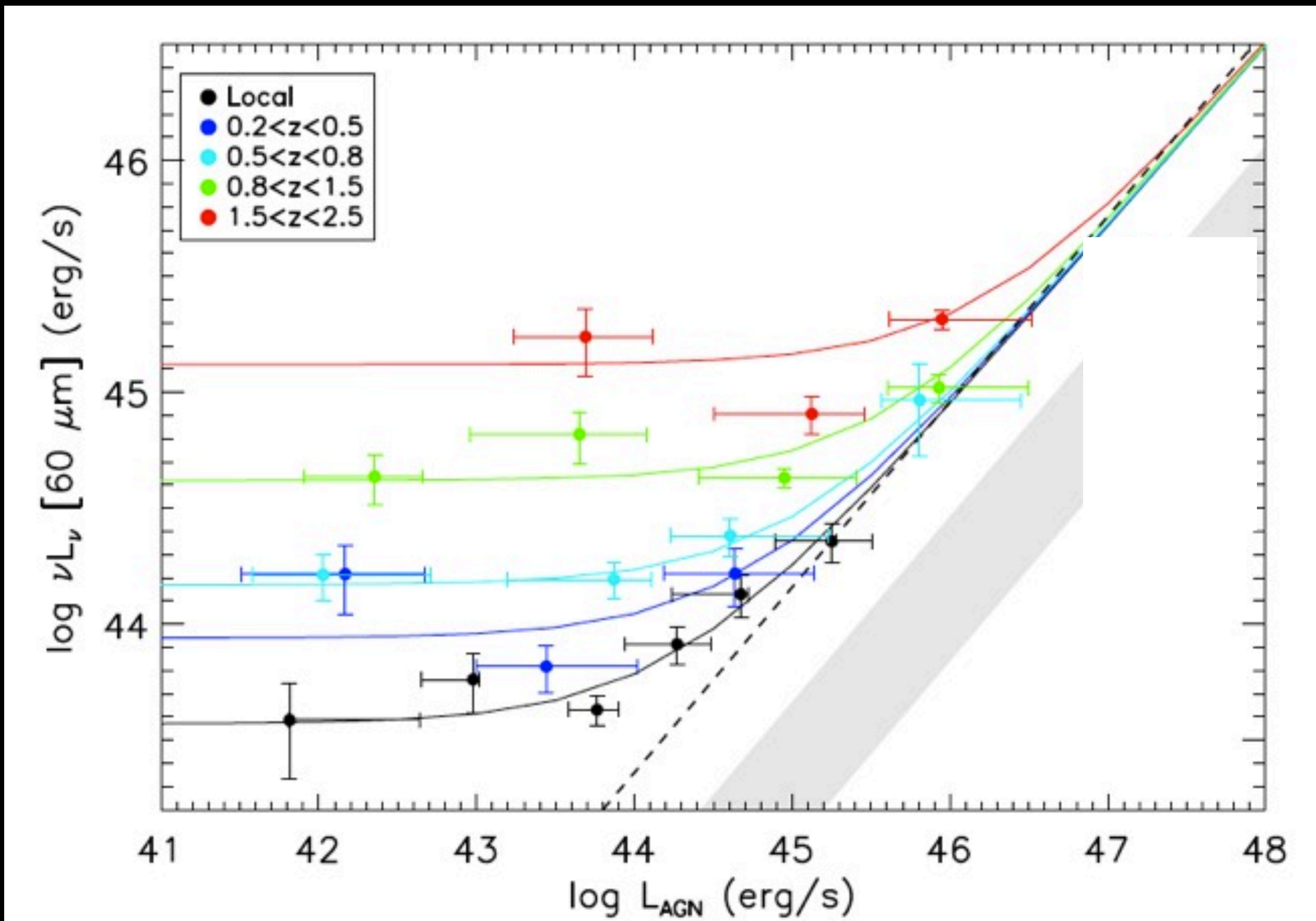
"more luminous AGN had the peak of activity at earlier redshifts"

see also Bongiorno et al. 2012
z-dependence of specific accretion rate:
$(1+z)^{4.2}$ at λ_{edd} = 10% Edd

[i.e. like the sSFR evolution in galaxy population, Karim + 2011, Pannella+2010]

2) Co-eval SF and accretion
SF vs. AGN luminosity

Rosario+2012
PEP / GOODS+COSMOS X-ray AGN



correlation between Lx and SF does not hold at low-L (see also Shao+2010)

evidence for dichotomy ...

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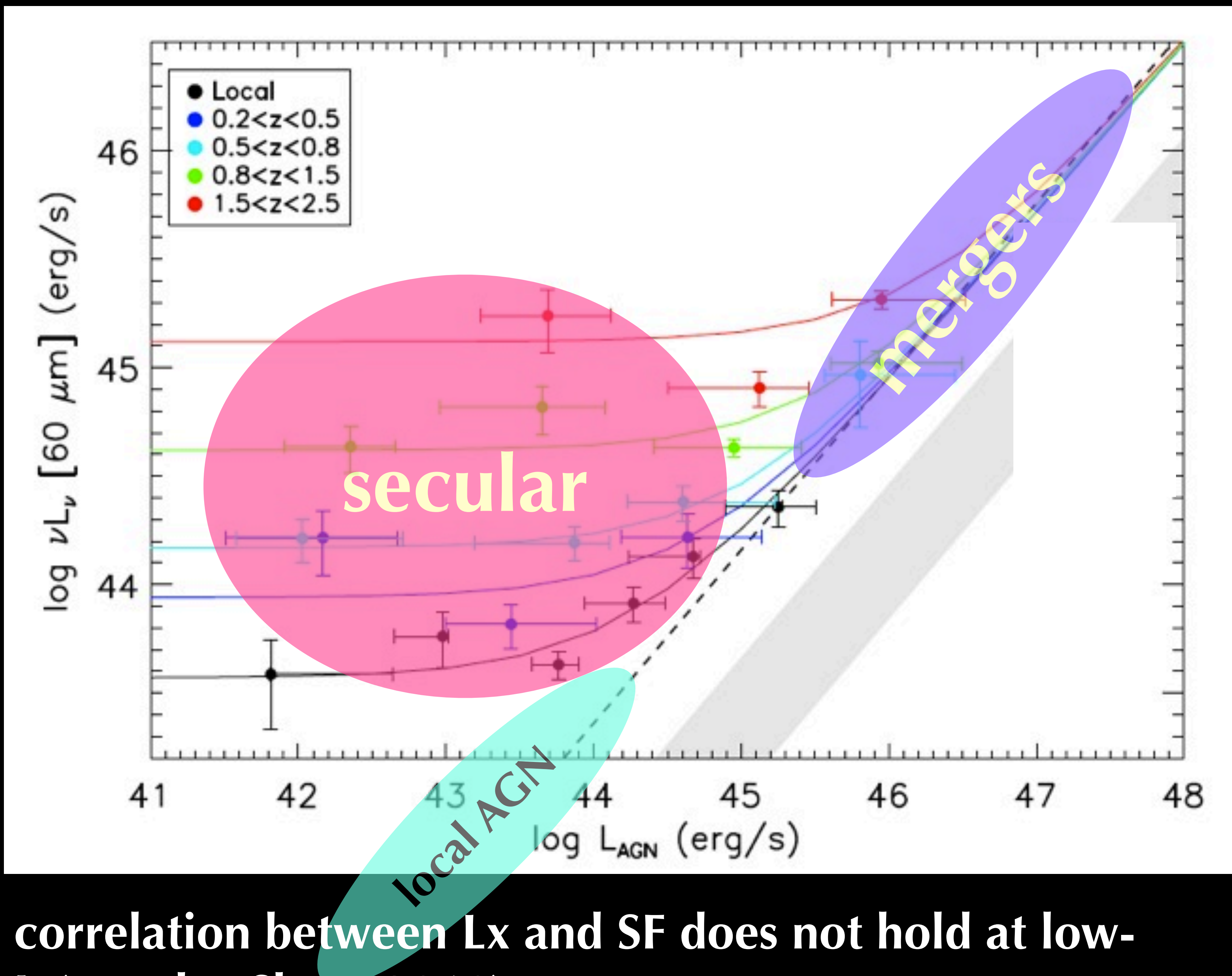

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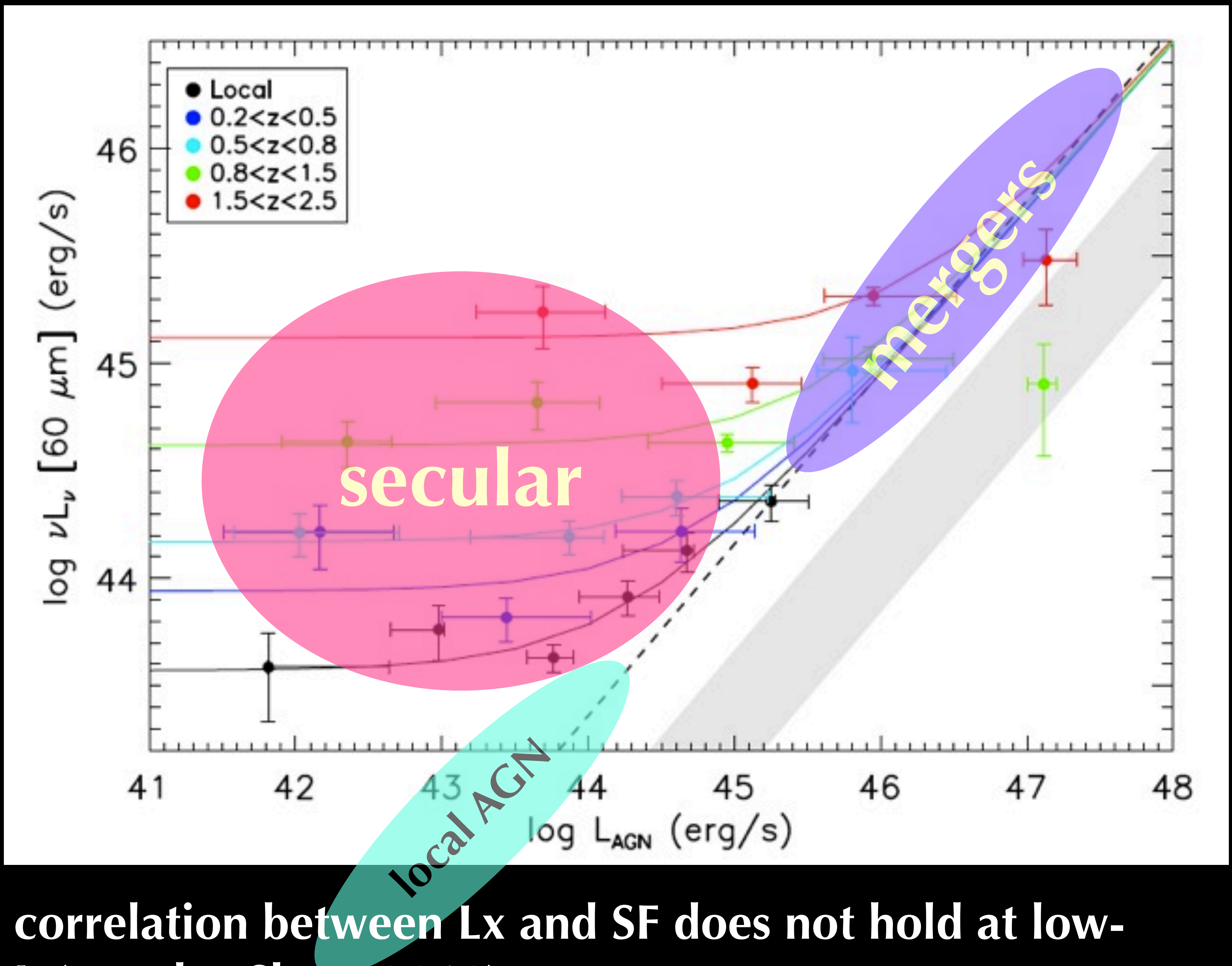


very high L(AGN) > 46 : "controversial" results and interpretations....

1) at high-z, high-L mergers not important, same secular processes as low-z, low-L are in place

2) SF-AGN synchronization is lost at high-z (Rosario + 2012)

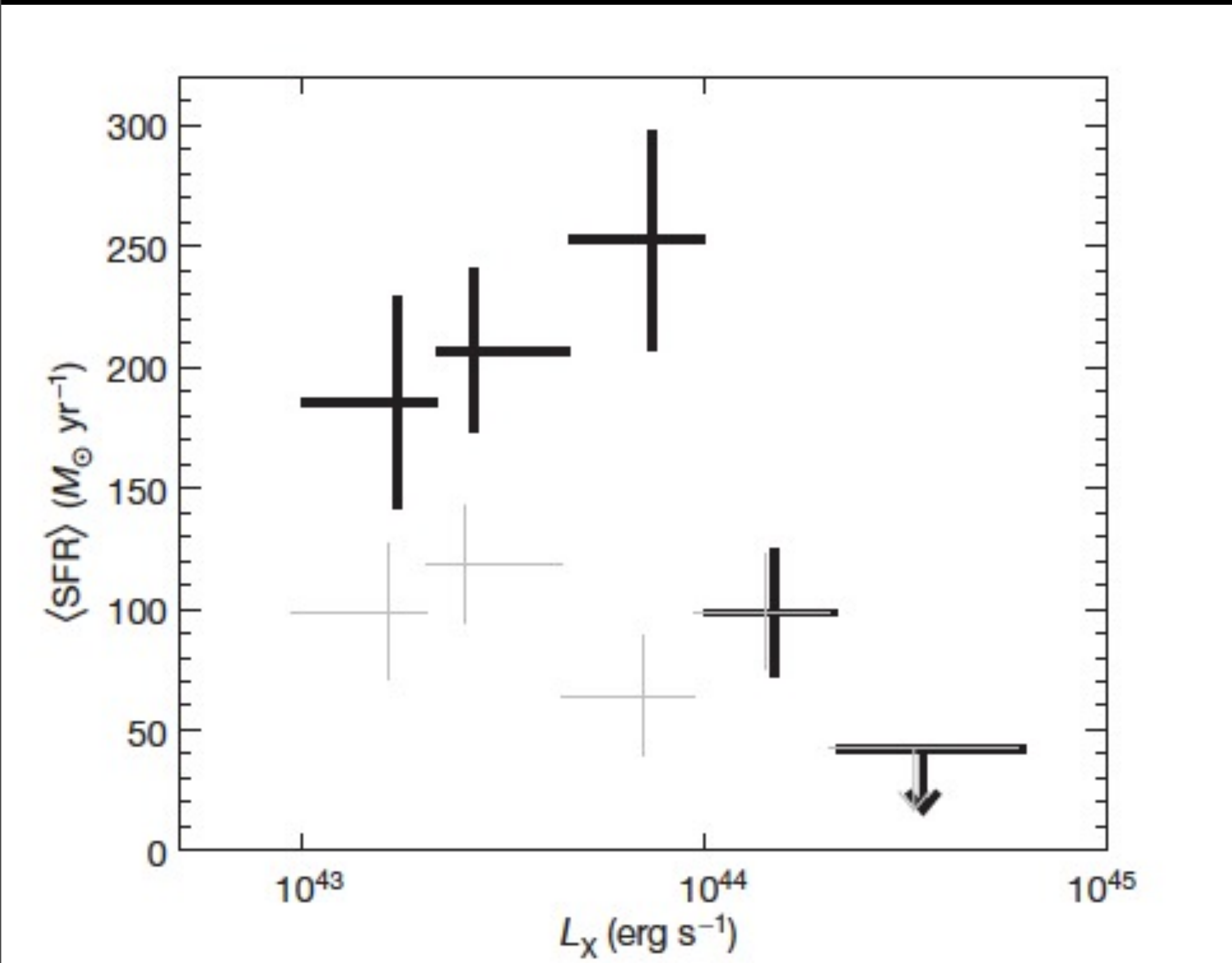
possible interpretation: effect of "feedback" in stopping SF

correlation between Lx and SF does not hold at low-L (see also Shao+2010)

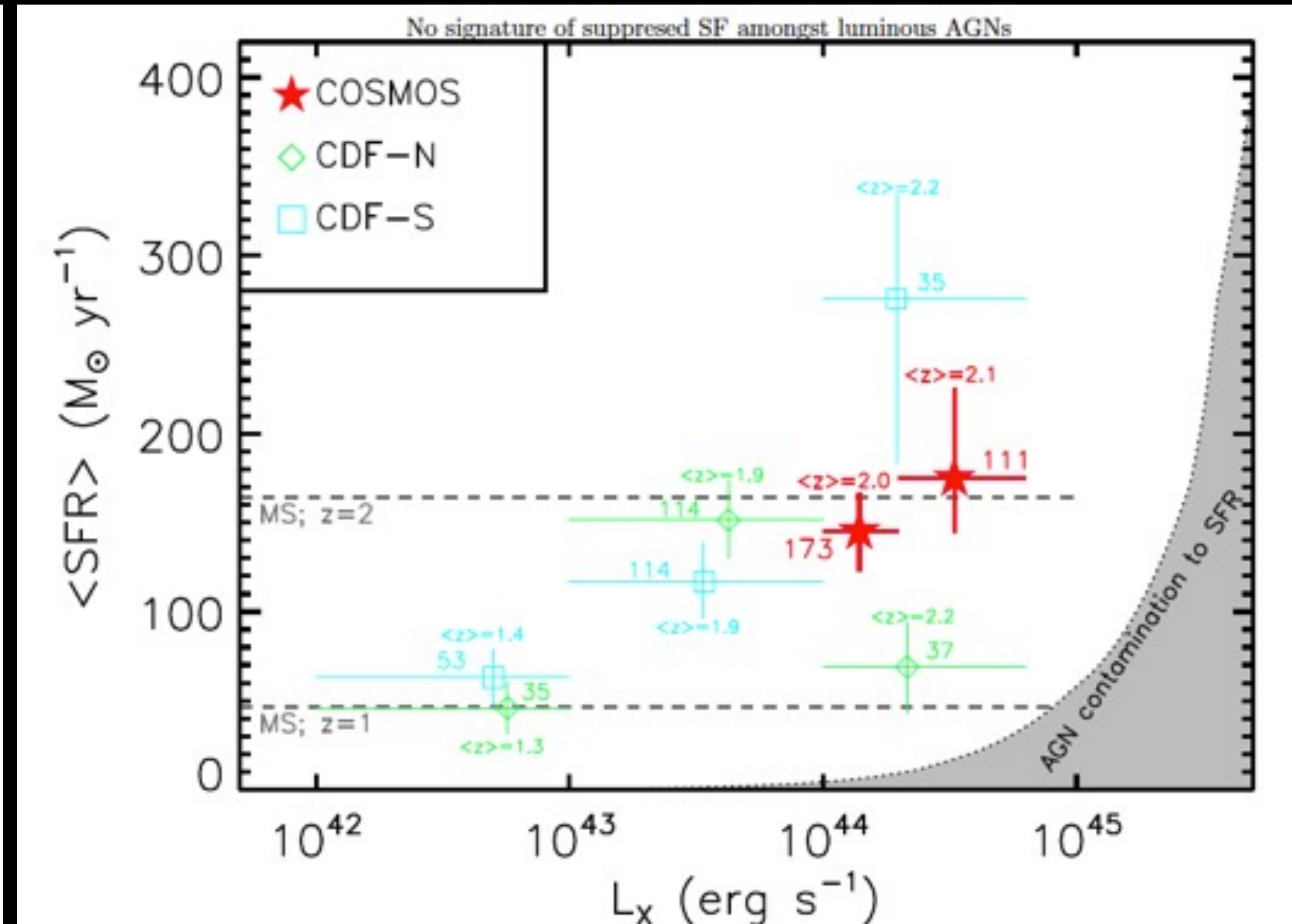
evidence for dichotomy ...

3) Evidence for Feedback?

Page+2012
Hermes/ CDFN X--ray AGN



Harrison+2012
CDFN/CDFS/COSMOS



SFR drops at Lx>44 in CDFN
-> evidence for "feedback" from AGN

different results on CDFN (green, drop), CDFS (cyan, increase!) and COSMOS (red, ~constant)
Huge cosmic variance problem!

N.B.: so far, feedback revealed as **molecular outflows** (CO broad wings, Feruglio et al. 2010) or **ionized outflows** (emission line kinematics, Cano-Diaz et al. 2012) **only in very bright** systems

Summary (I)

SF and AGN activity co-exist (e.g. same "downsizing", same redshift evolution for sSSFR and specific accretion rate), but very little knowledge on timescales/delays. They may share the same process of triggering, but there are not evidences yet that they trigger each other. Whatever physical process is responsible for triggering and fueling AGN and SF activity must decrease in frequency with cosmic time.

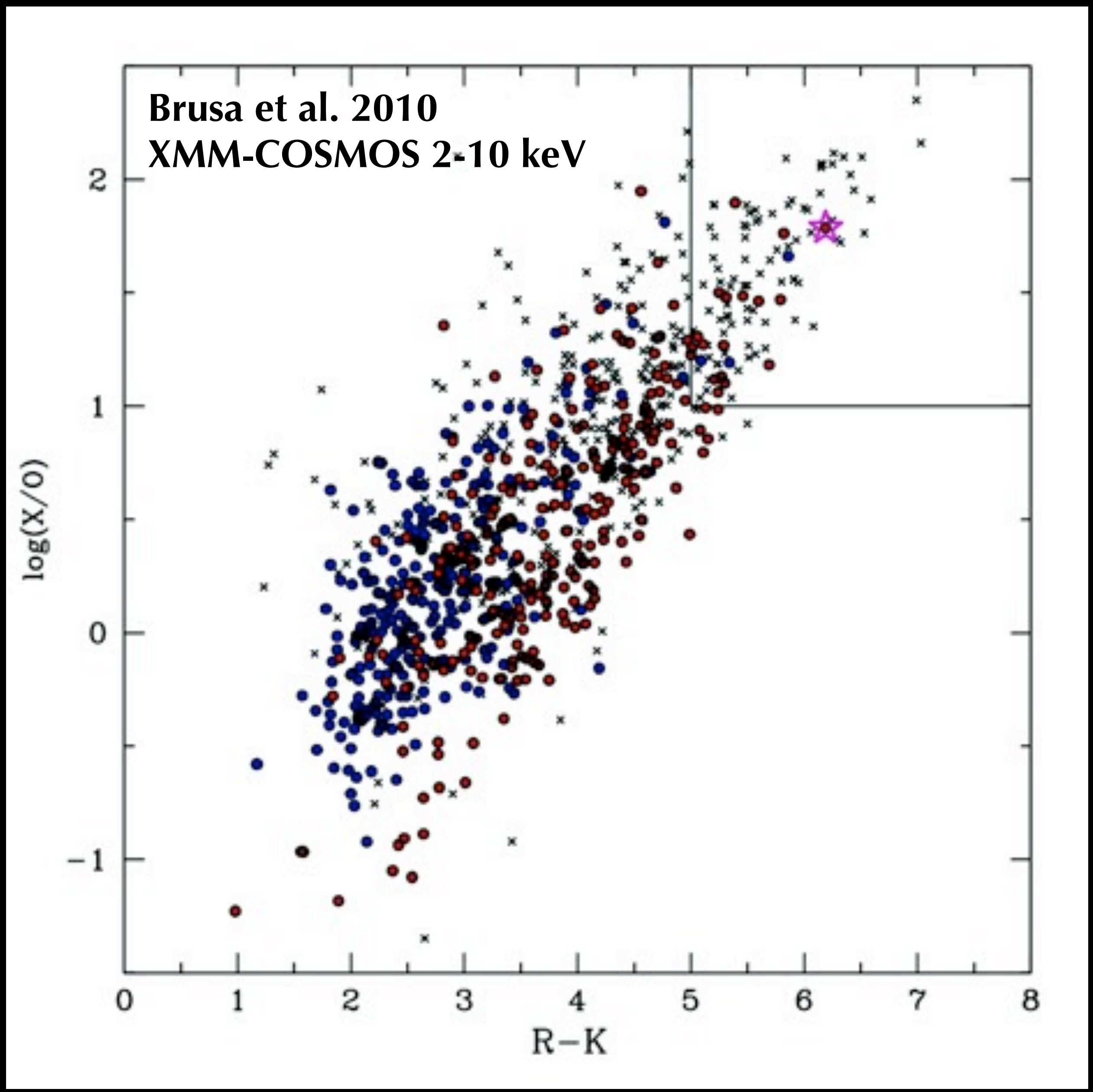
There are evidences for mergers "conditions"(e.g. obscured fraction increases with z.. to be confirmed!) but no direct evidence for feedback or feedback effects (e.g. no shutdown of SF is proven) in L* objects - except the very brightest, local ones

Luminosity effect is clearly in place (e.g. SF vs. Lx), but current surveys do not probe with enough statistics the "critical" range (logLx=logL*+/-0.5).
Huge "cosmic variance" problem.

LUMINOUS OBSCURED QSOs best laboratory ....

INTERMEZZO (3)
HOW to efficiently isolate obscured QSO

Use correlations between observables (X/O, R-K, HR, luminosities) for the identified samples to isolate obscured AGN



Most efficient selection to pick up obscured QSO using only 3 bands!
Also "pure" X-ray selection (NH>22 and Lx>44, see Manieri et al. 2011)

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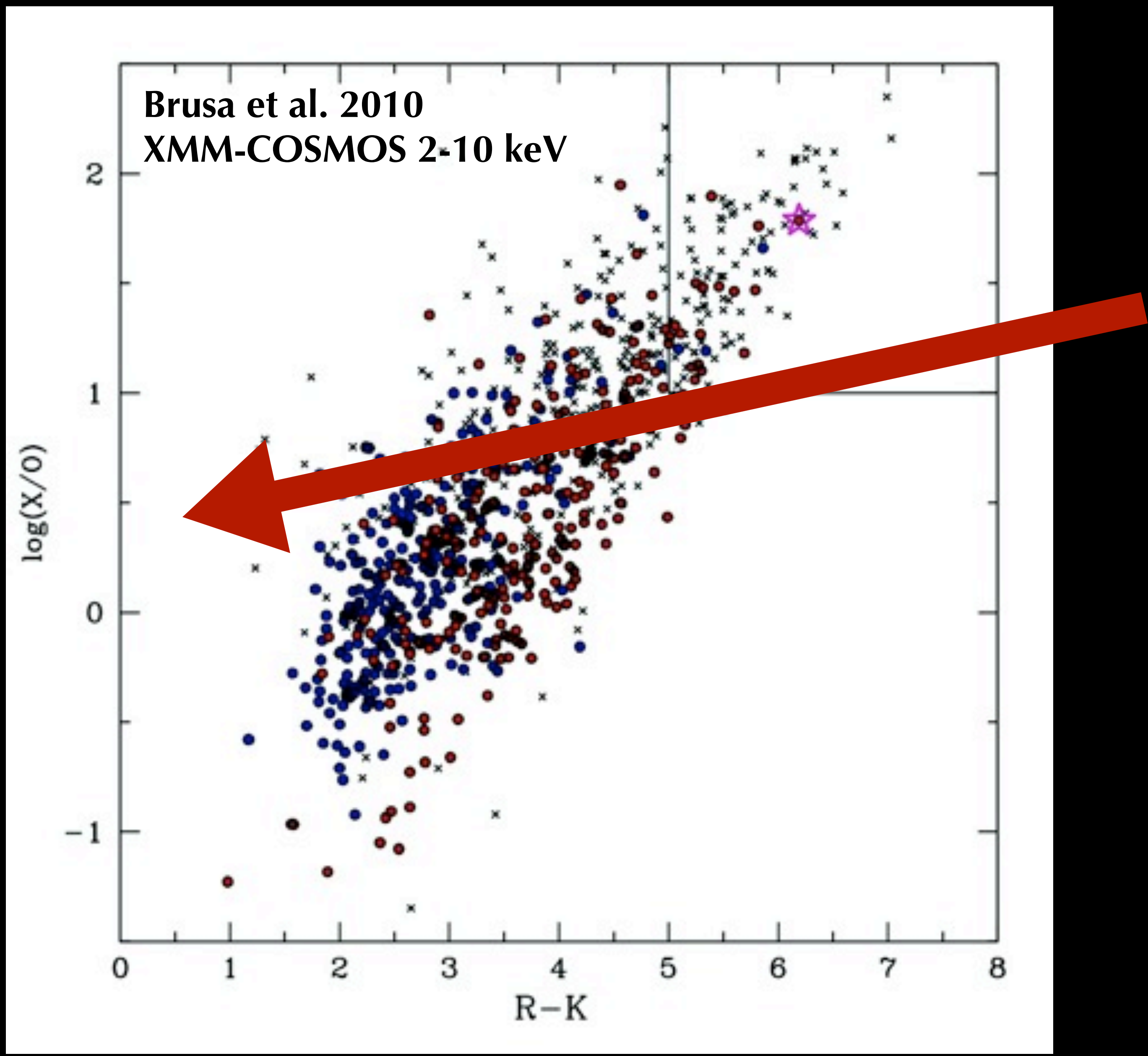

X/O correlates with Lx for obscured AGN (proposed by Fiore, MB+03; see also Barger+05, Eckart+06 etc.)

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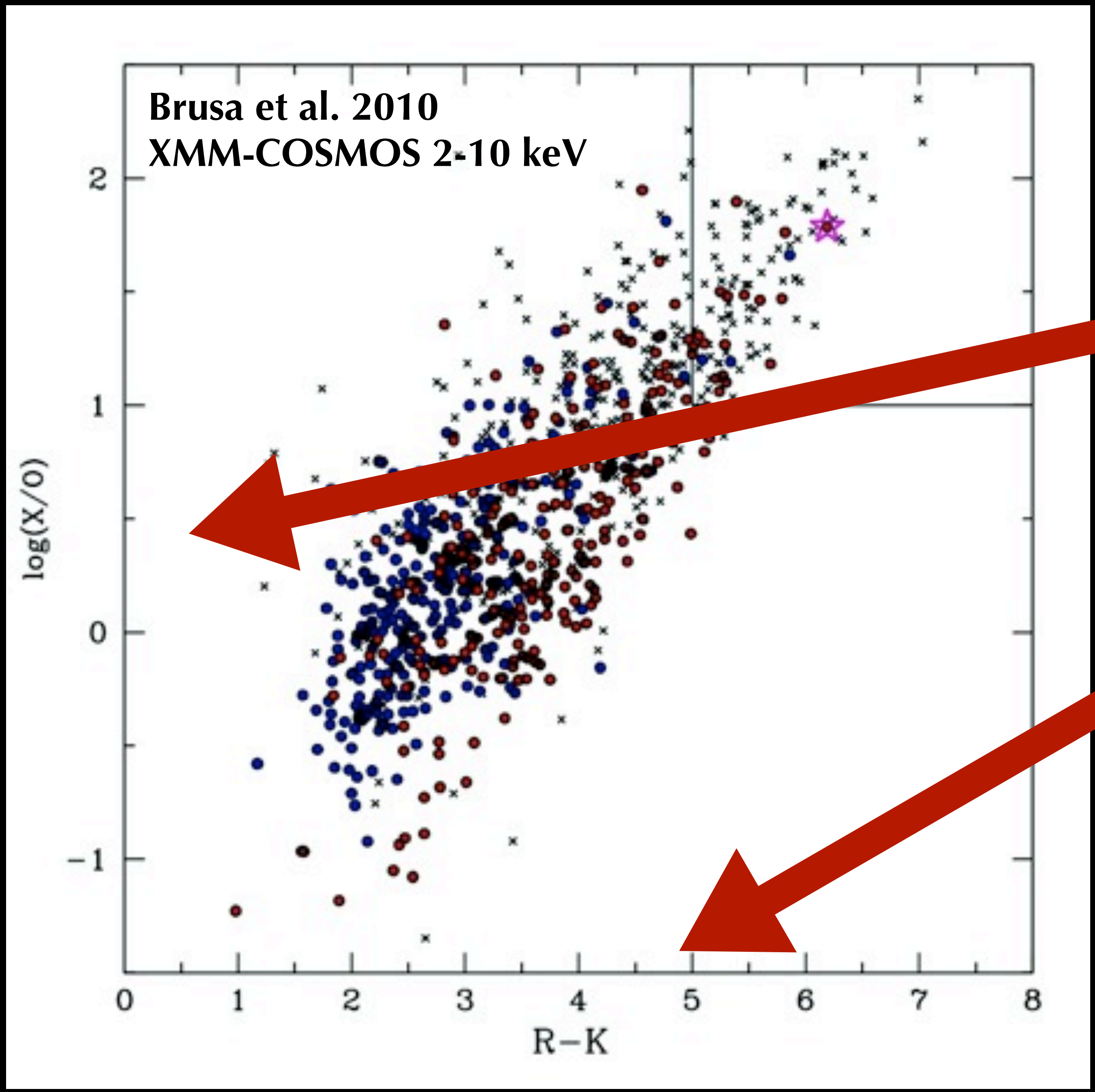

X/O correlates with Lx for obscured AGN (proposed by Fiore, MB+03; see also Barger+05, Eckart+06 etc.)

obscured sources are RED (Alexander et al. 2011, Mignoli+2004, Brusa +2005; 2009)

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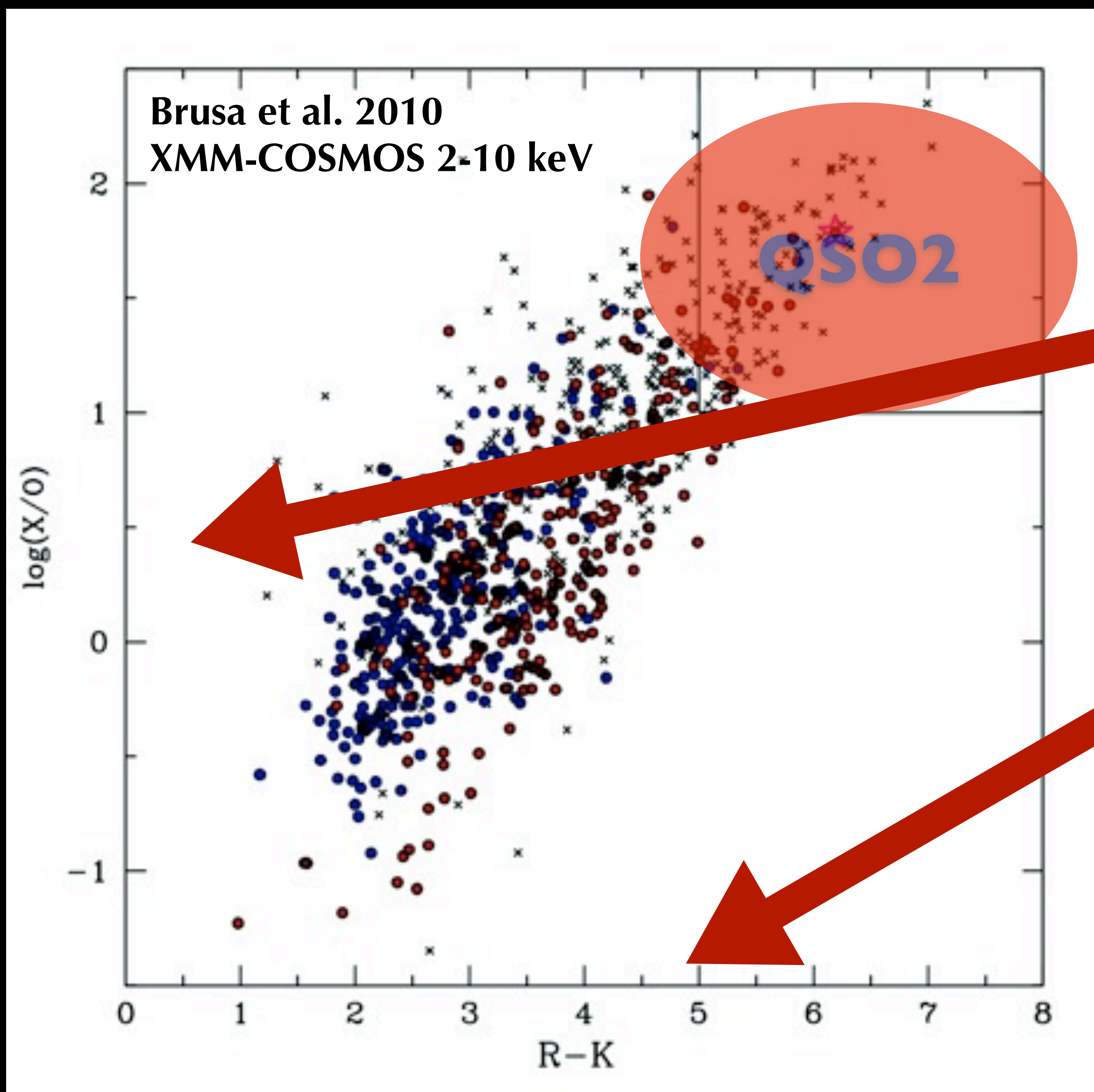

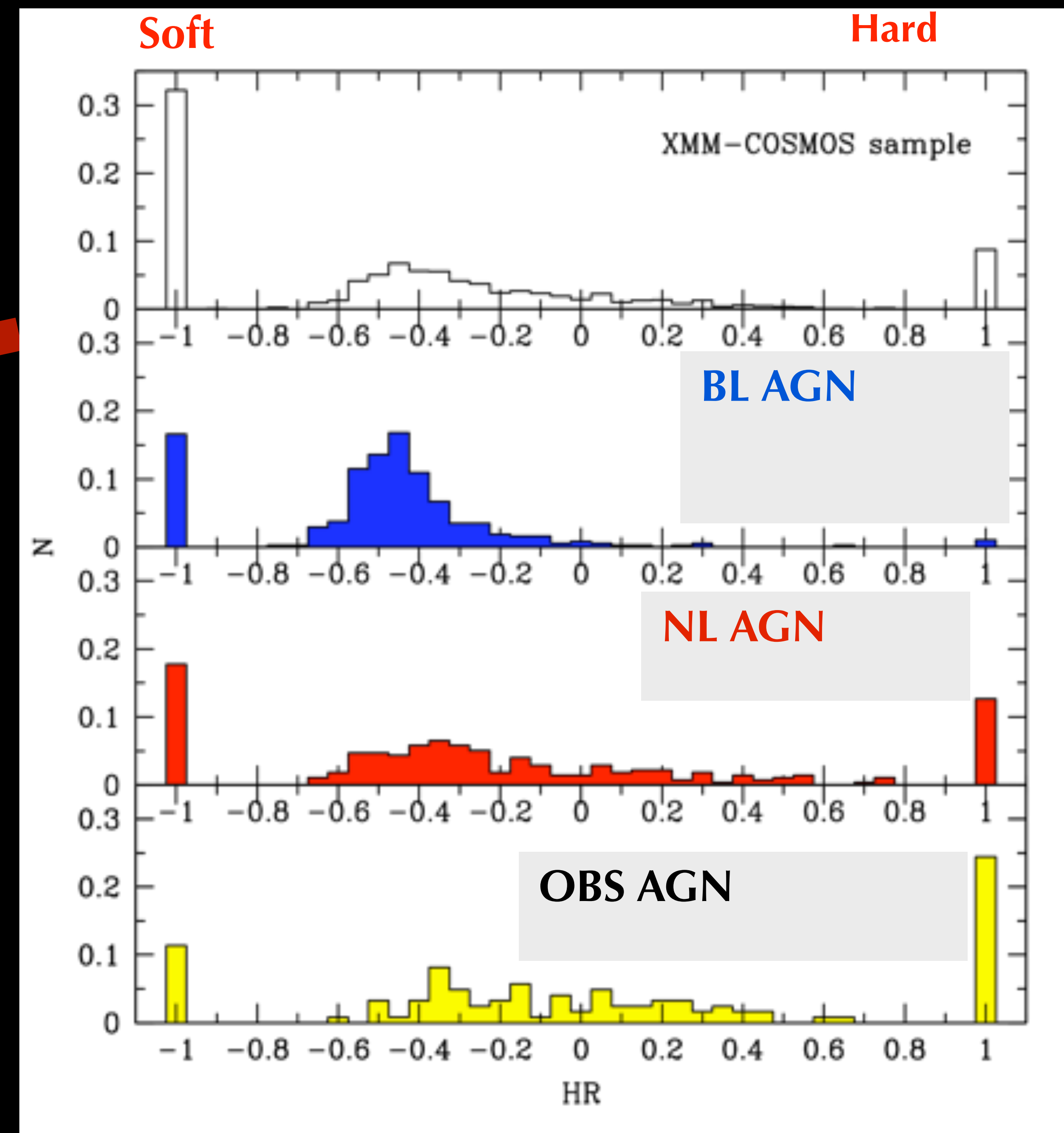

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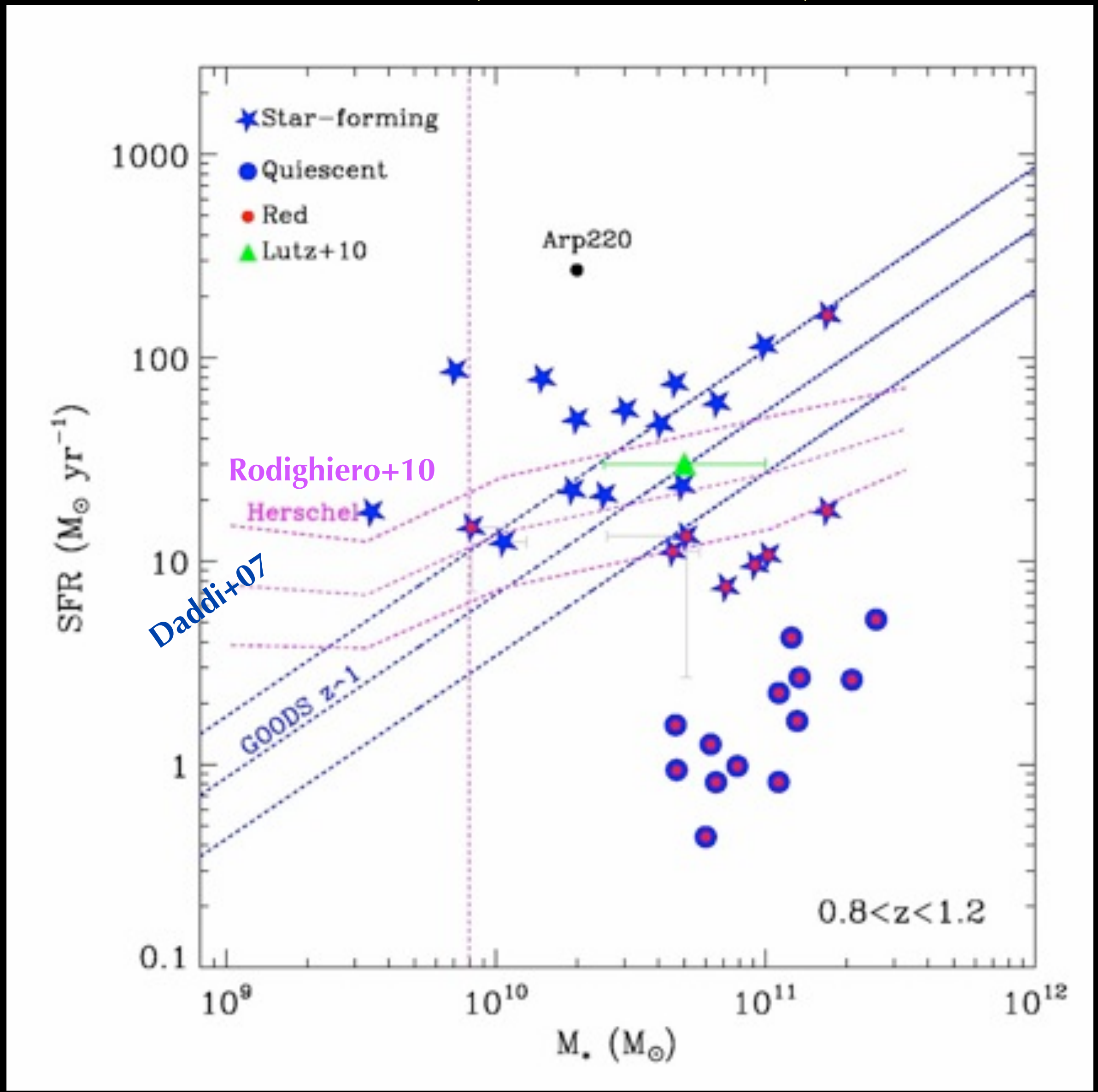
How to place objects in the mergers sequence ?

Most **luminous**, **obscured X-ray selected** sources at z>1 are red
--> effect of (negative) feedback efficient in stopping star formation, or
AGN is in dusty environment? Evidences for ***both*** !

Mainieri et al. 2011 (QSO2 in COSMOS, Lx>44)
see also Brusa+2009, Lusso+2011, Rovilos+2012



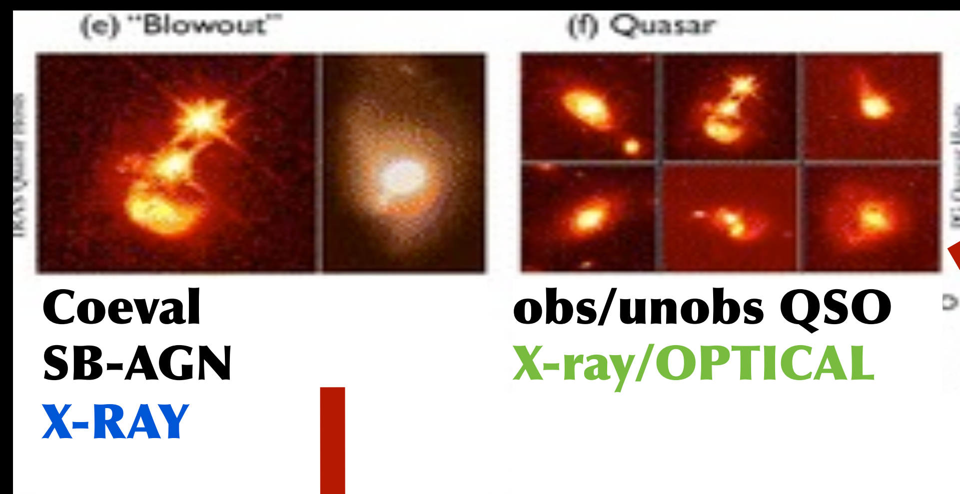
Same level of starformation for"active" (AGN) and "inactive" (SF) galaxies (see Bongiorno et al. 2012)

QSO2 hosts follow the tight correlation between SFR and M_* of blue star-forming galaxies (e.g. Noeske+07; Daddi+07; Elbaz+07; Rodighiero+10 / **Herschel**)

"Passive" population also present !

Merger sequence

Compton
Thick
(not sampled)



QSO1 (BL AGN)
no obscuration

"passive" QSO2
obscuration = torus

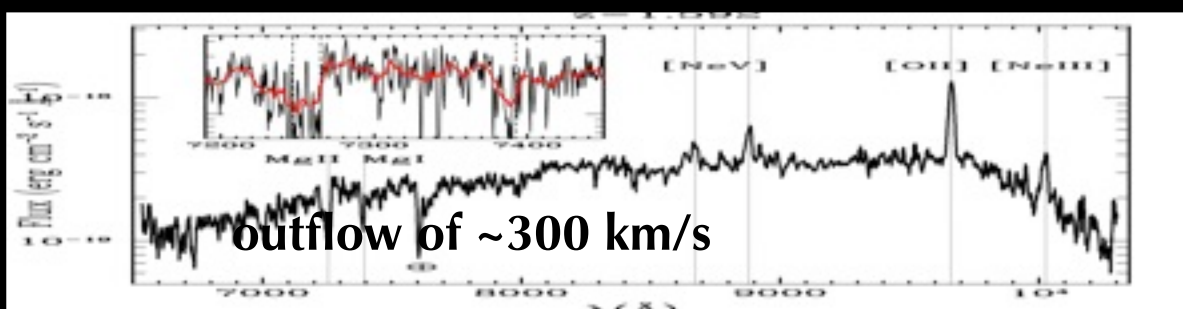
SF QSO2
obscuration = torus and/or galaxy

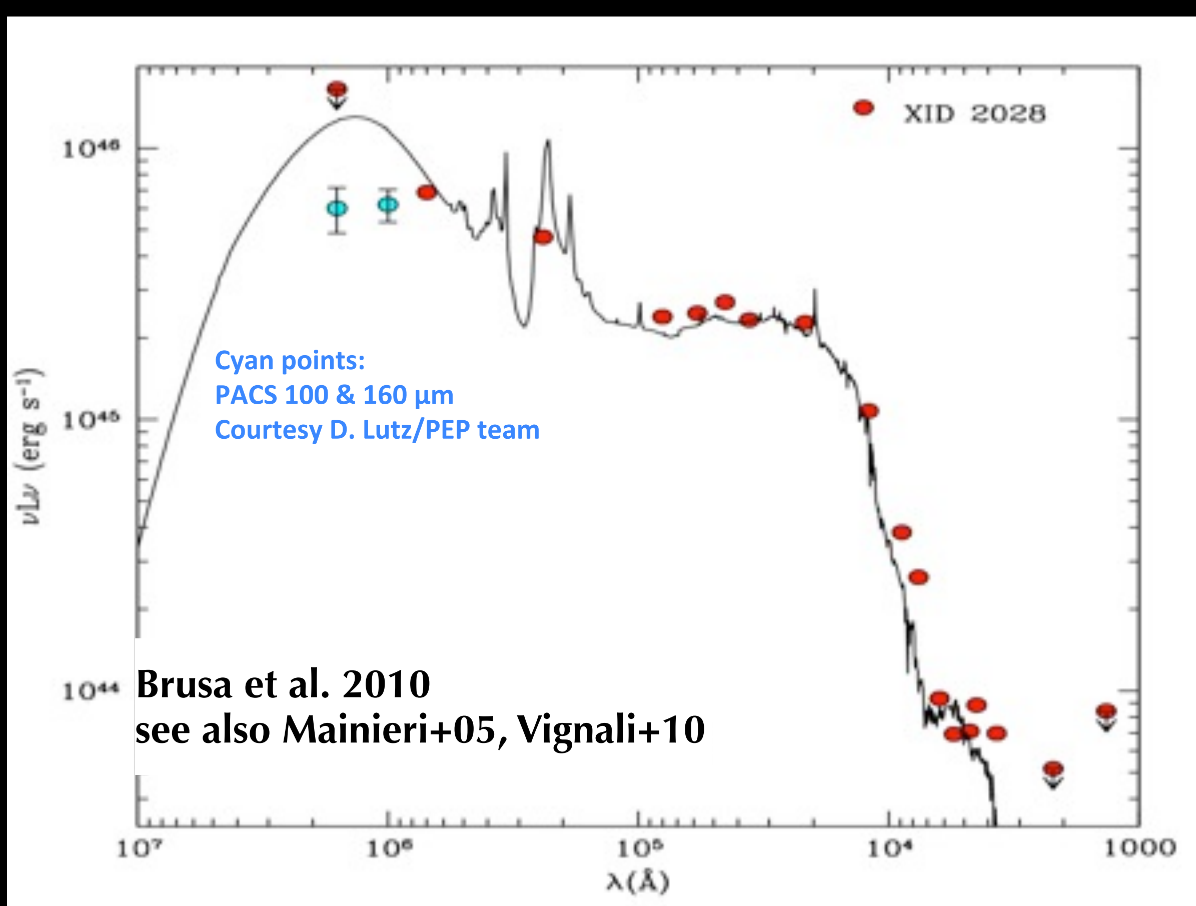
During or Post ?

X-ray obscured selection sample

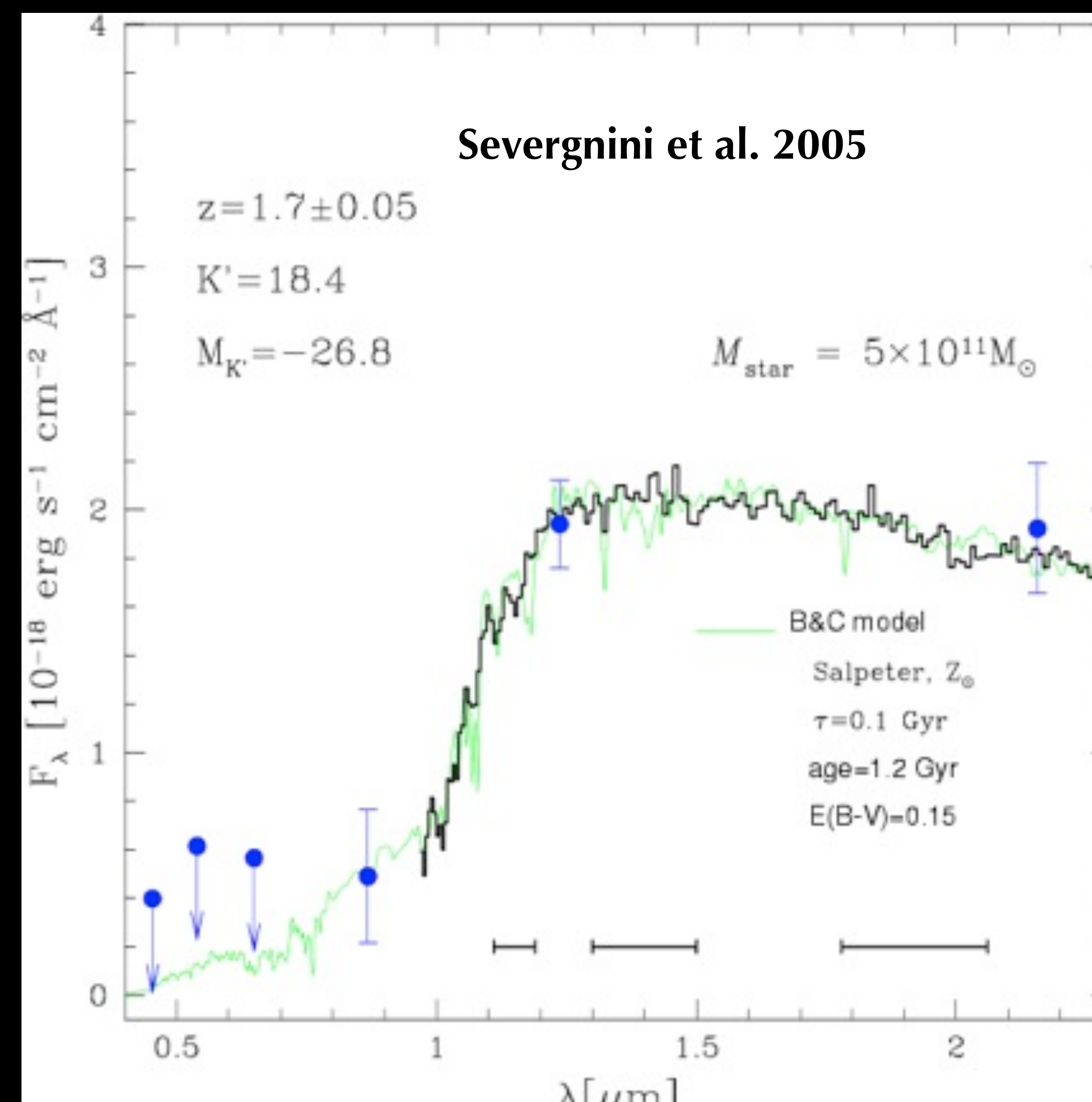
different phases/timescales

evidence of SF both in FIR and optical spectra





passive ellipticals/early type spectra without any sign of SF (see also Mignoli+2004, Brusa+2005, Daddi +2005....)



How to test models?
(1) BH masses

zero-th order predictions:

1) unobscured AGN are subsequent phase of obscured QSO -->
BH masses of unobscured AGN should be higher than those of X-ray obscured AGN.

2) unobscured AGN are a subsequent phase of **SF** obscured QSOs **-->**
BH masses of unobscured AGN should be higher than those of X-ray obscured **SF** QSOs.
(**BH masses of "passive" QSO2 should be higher than those of SF QSO2)**

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(**BH masses of "passive" QSO2 should be higher than those of SF QSO2)**

BH masses for X-ray obscured AGN at z>1 can be obtained with IR spectroscopy (Halpha redshifted in NIR); some dedicated programs started to exploit NIR spectrograph, such as SINFONI, XSHOOTER, ISAAC, FMOS, LUCIFER etc.

How to test models?
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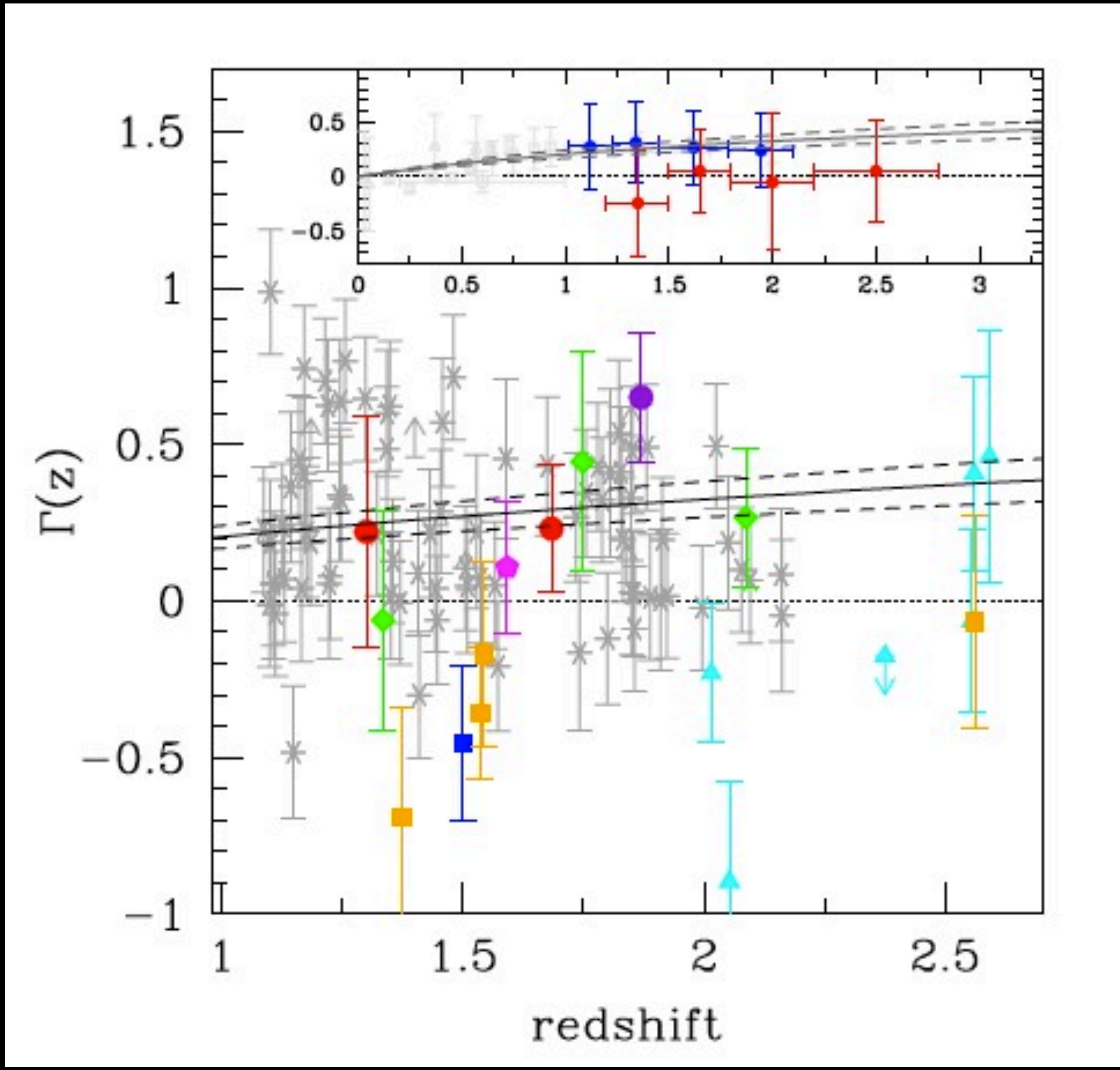

BH masses for ~20 obscured AGN compared to BL AGN (Bongiorno et al. 2013)

- unobscured AGN are subsequent phase of obscured AGN --> BH masses of unobscured AGN should be higher than those of X-ray obscured AGN.
- X-ray Obscured QSOs tend to have a MBH-Mstar ratio consistent with the local one, while BL AGN have a higher ratio (Bongiorno et al. 2013)
- For a given M*, this is consistent with obscured AGN having a smaller BH mass than unobscured AGN
- BUT... the observed lower ratio can be reproduced also with the same BH mass of BL AGN and a larger M* --> same "phase" as BL AGN, and obscuration is only from the torus (unified model)

How to test models?
(1) BH masses

passive QSO2 are a subsequent phase of SF QSO2-->
BH masses of "passive" QSO2 should be higher than those of SF QSO2

- current observations of obscured AGN at z>1 are on (small) sparse samples at different Lx, and other wavelength info <u>is not homogeneous.</u>

- **15** QSO2 at z~1.5 from XMM-COSMOS **to be observed** with Xshooter! (SF properties very well constrained from PEP/SED fitting)

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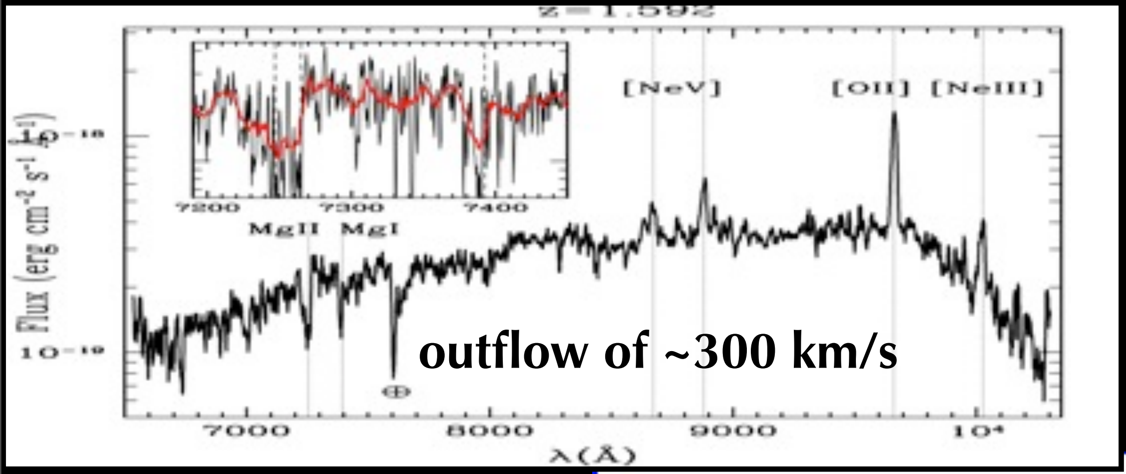
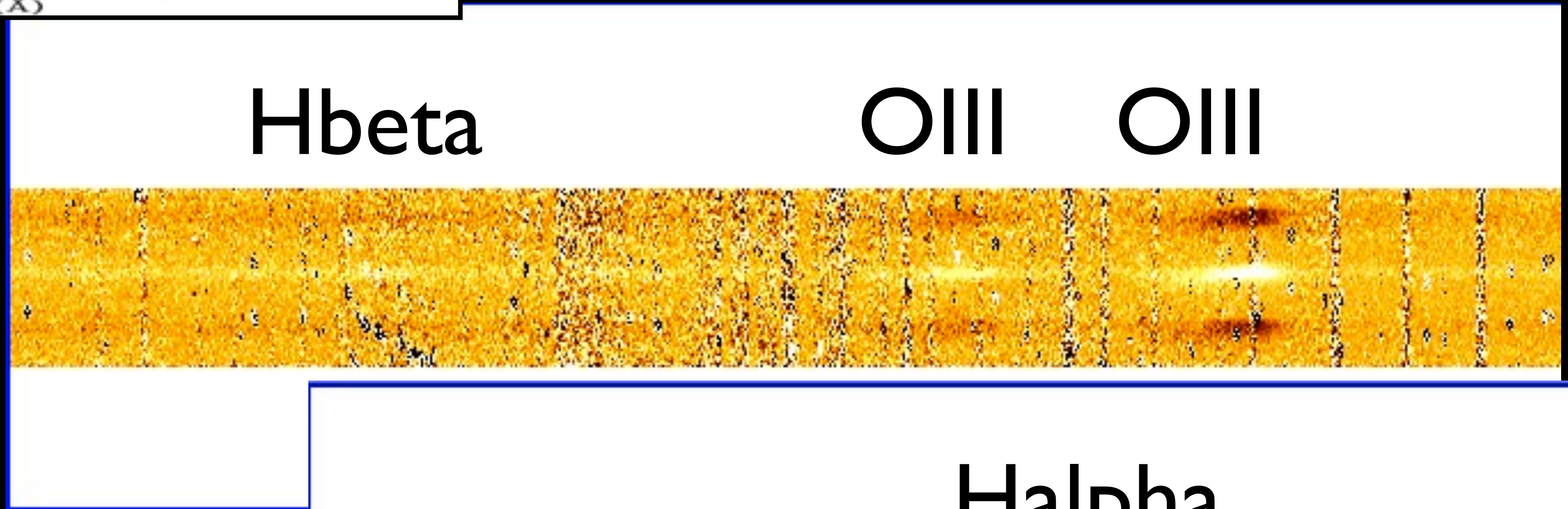
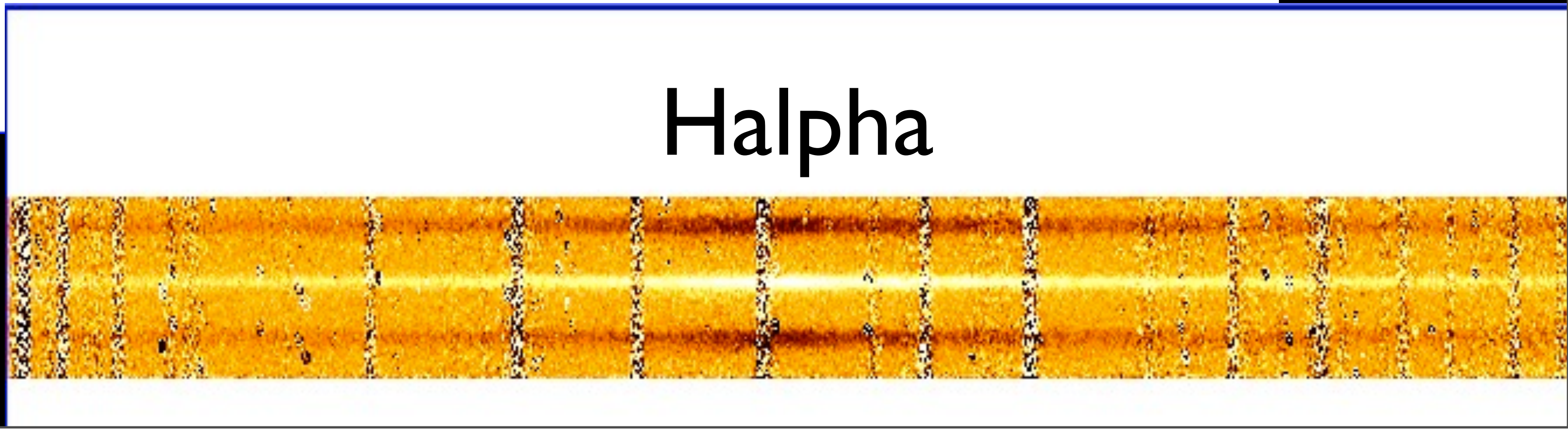
X-shooter spectrum of XID 2028

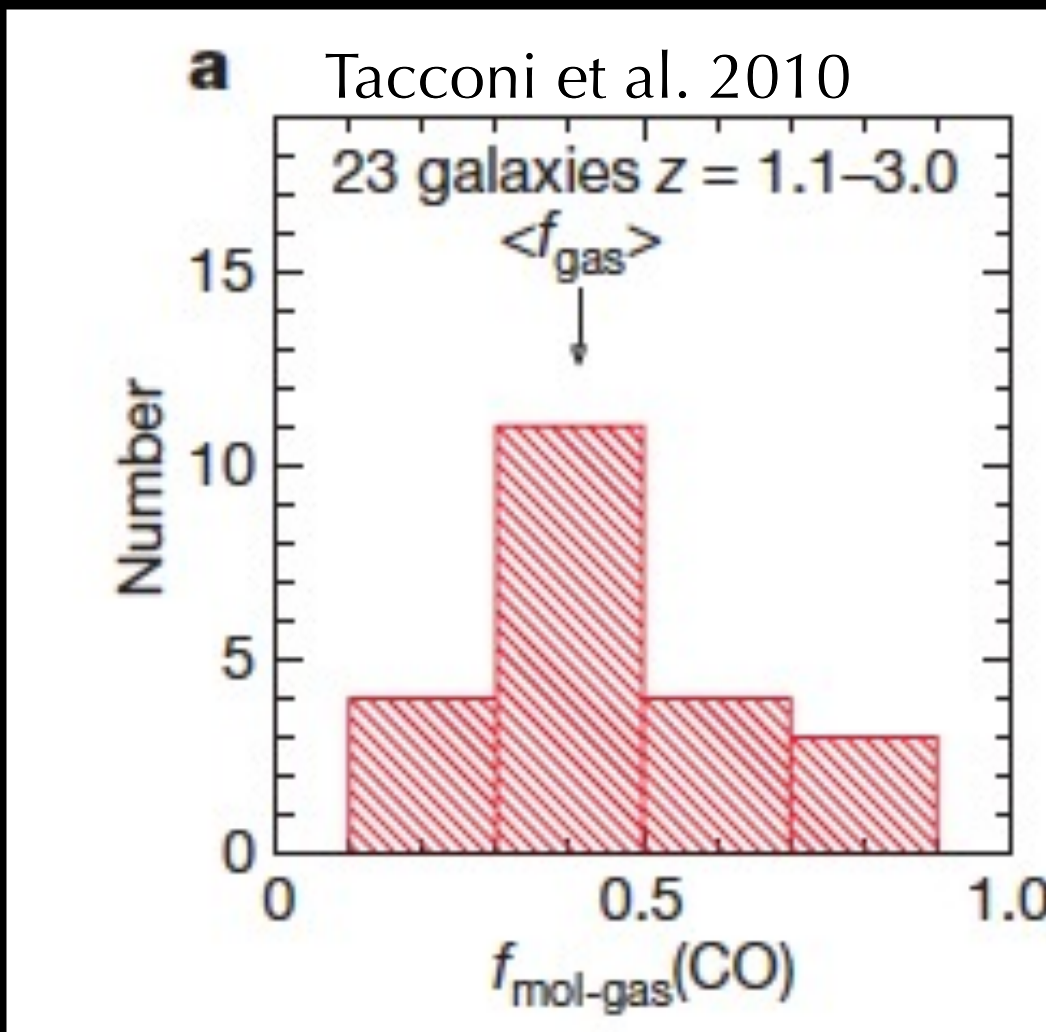




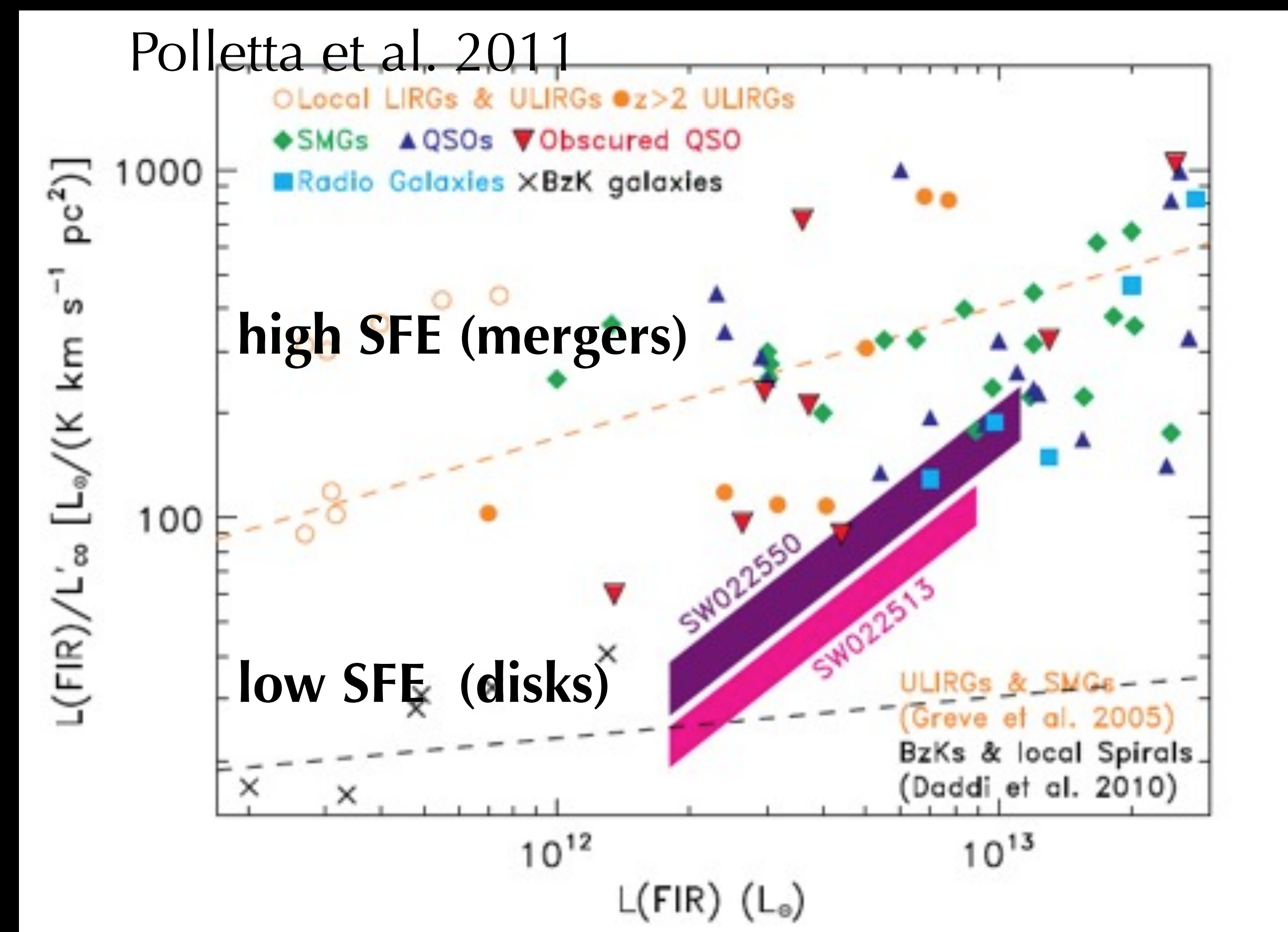


How to test models?
(2) Cold Gas Mass

- If mergers scenario hold: Gas mass in SF QSO2 (still available) should be higher than in passive QSO2 (already diminished/exhausted) --> CO luminosities vs. LIR / SFE (IRAM + ALMA programs). Molecular gas kinematics



IRAM detection of BzK and SMG gas fraction higher than in local SB. Time to extend these studies to AGN and larger samples --> ALMA!



IRAM/ALMA studies so far limited to high-z QSOs and "SF" systems. Observations of PASSIVE QSO2 key to test (or falsify) merger models

Summary

SF and AGN activity co-exist (e.g. same "downsizing", same redshift evolution for sSSFR and specific accretion rate), but very little knowledge on timescales/delays. They may share the same process of triggering, but there are not evidences yet that they trigger each other. Whatever physical process is responsible for triggering and fueling AGN and SF activity must decrease in frequency with cosmic time.

There are evidences for mergers "conditions"(e.g. obscured fraction increases with z) but no direct evidence for feedback or feedback effects (e.g. no shutdown of SF is proven) in L* objects - except the very brightest, local ones

Luminosity effect is clearly in place (e.g. SF vs. Lx), but current surveys do not probe with enough statistics the "critical" range (logLx=logL*+/-0.5).
Huge "cosmic variance" problem.

Lot of information already in place, but critical parameters (BH masses, gas masses) for obscured QSOs over a wide range of SF properties still missing. Exciting perspective for NIR spectroscopy and ALMA -> STAY TUNED !!!!!

The golden epoch of multi-wavelength synergies

Gas mass
(CO lines)

ALMA/IRAM

Herschel

SFR
(FIR fitting)

Stellar mass
(SED fitting)

Subaru/
CFHT/
Spitzer

VLT/
Keck

ACS +
WFC3

X-shooter/
Sinfoni/FMOS/
NICS/Lucifer

Chandra/
XMM

Morphologies

BH mass
(broad lines)

SMBH
growth rate
(X-ray lum)

The (next) golden epoch of multi-wavelength synergies

Gas mass
(CO lines)

ALMA/
SKA

SPICA

SFR
(FIR fitting)

Stellar mass
(SED fitting)

LSST/Euclid

E-ELT/
Euclid

JWST

KMOS/
JWST/Euclid

?
(eROSITA)

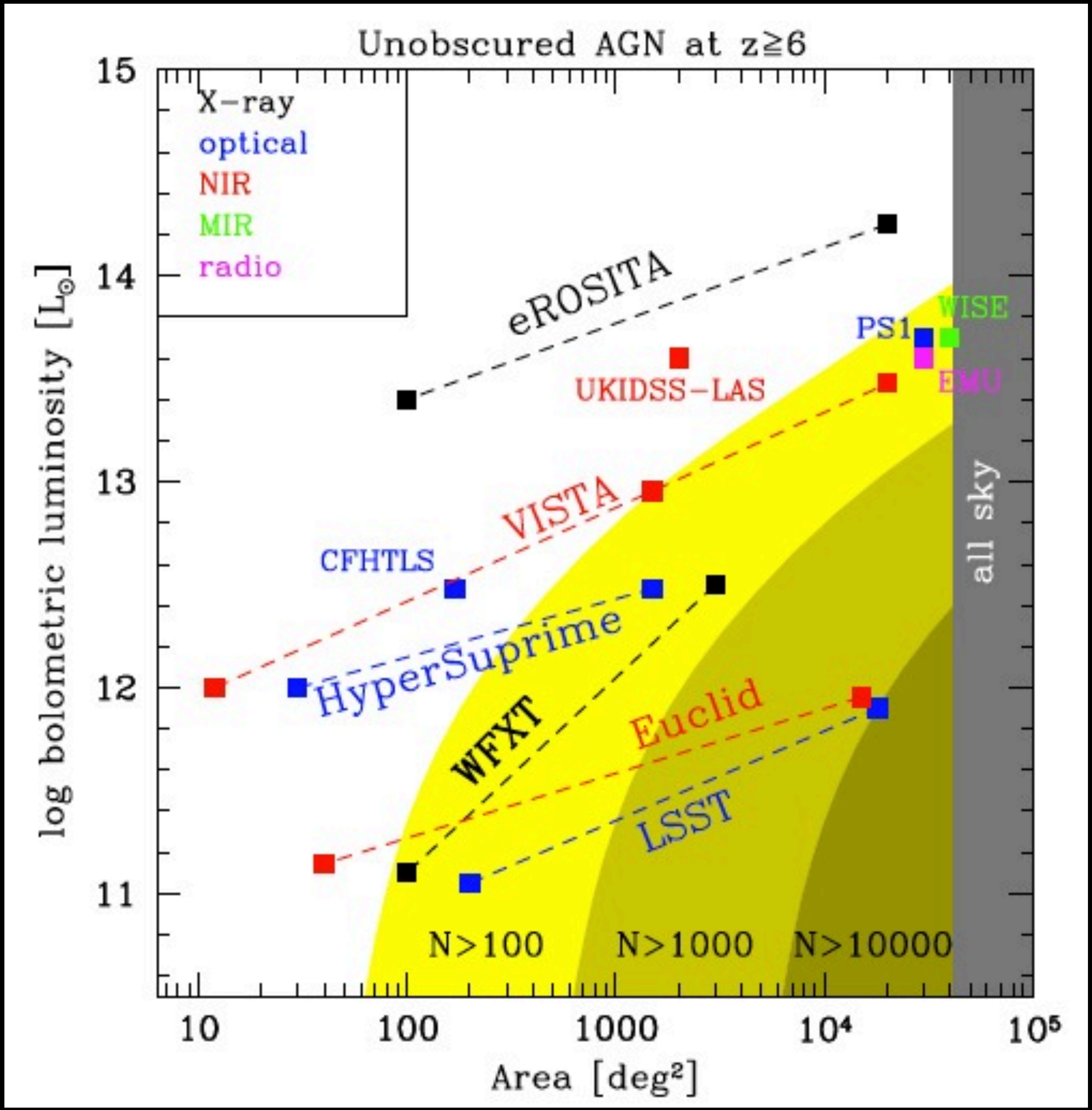
Morphologies

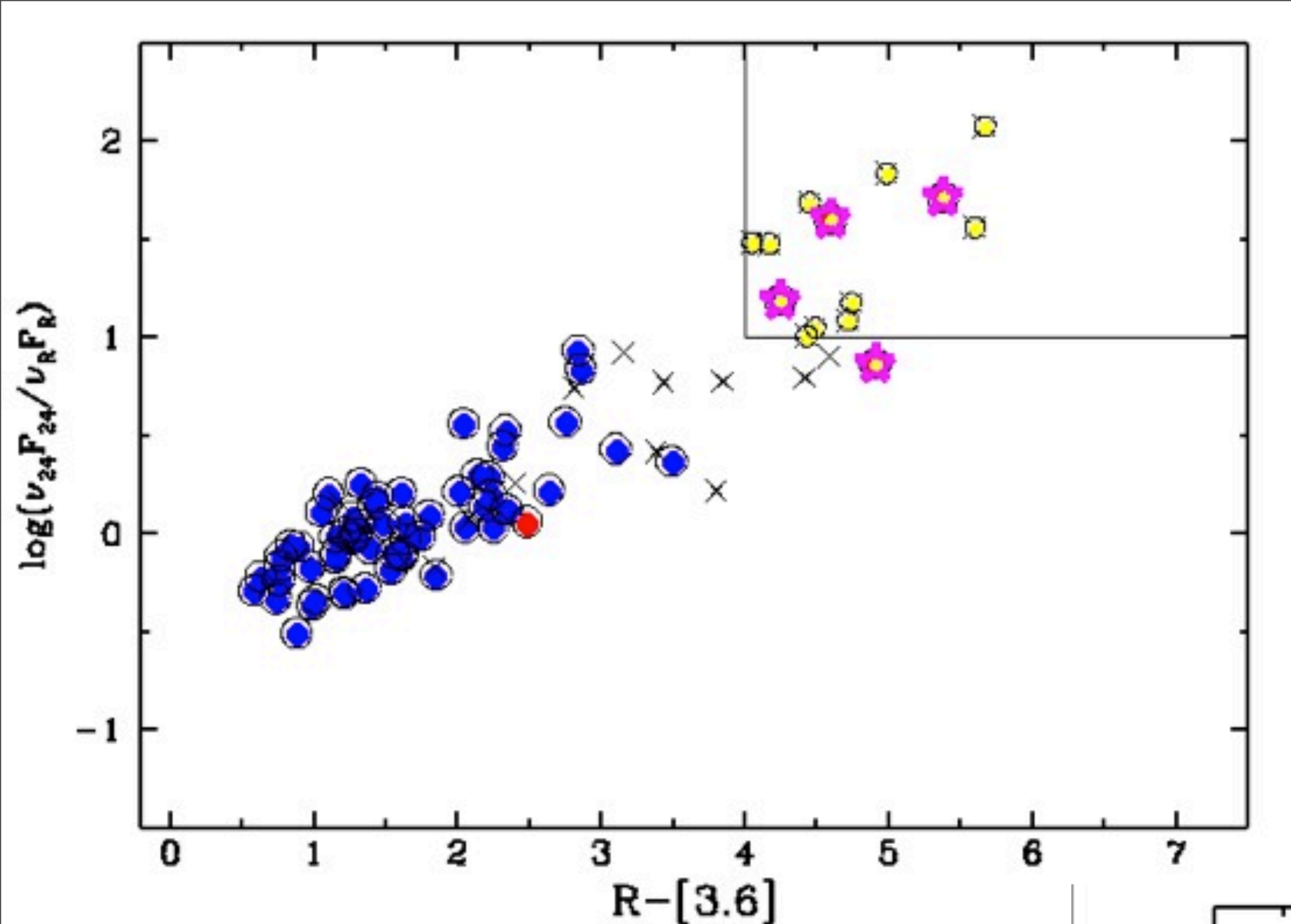
BH mass
(broad lines)

SMBH
growth rate
(X-ray lum)


Thanks !

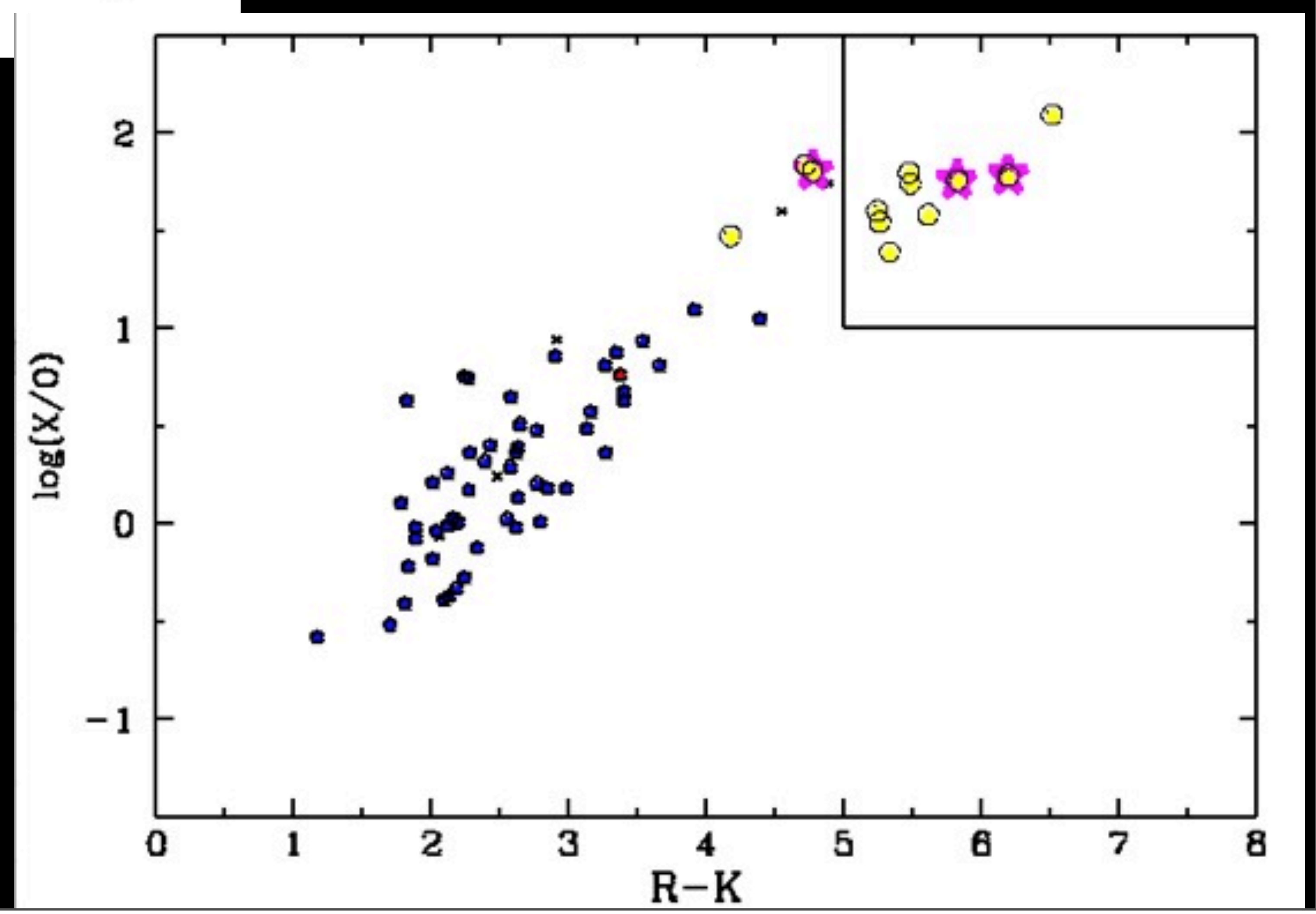
Backup


Unobscured AGN at z≧6
X-ray
optical
NIR
MIR
radio
eROSITA
UKIDSS-LAS
PS1
WISE
EMU
VISTA
CFHTLS
HyperSuprime
WFXT
Euclid
LSST
all sky
N>100
N>1000
N>10000
log bolometric luminosity [L☉]
Area [deg²]
15
14
13
12
11
10
100
1000
10⁴
10⁵



selection:
yellow (+magenta) points

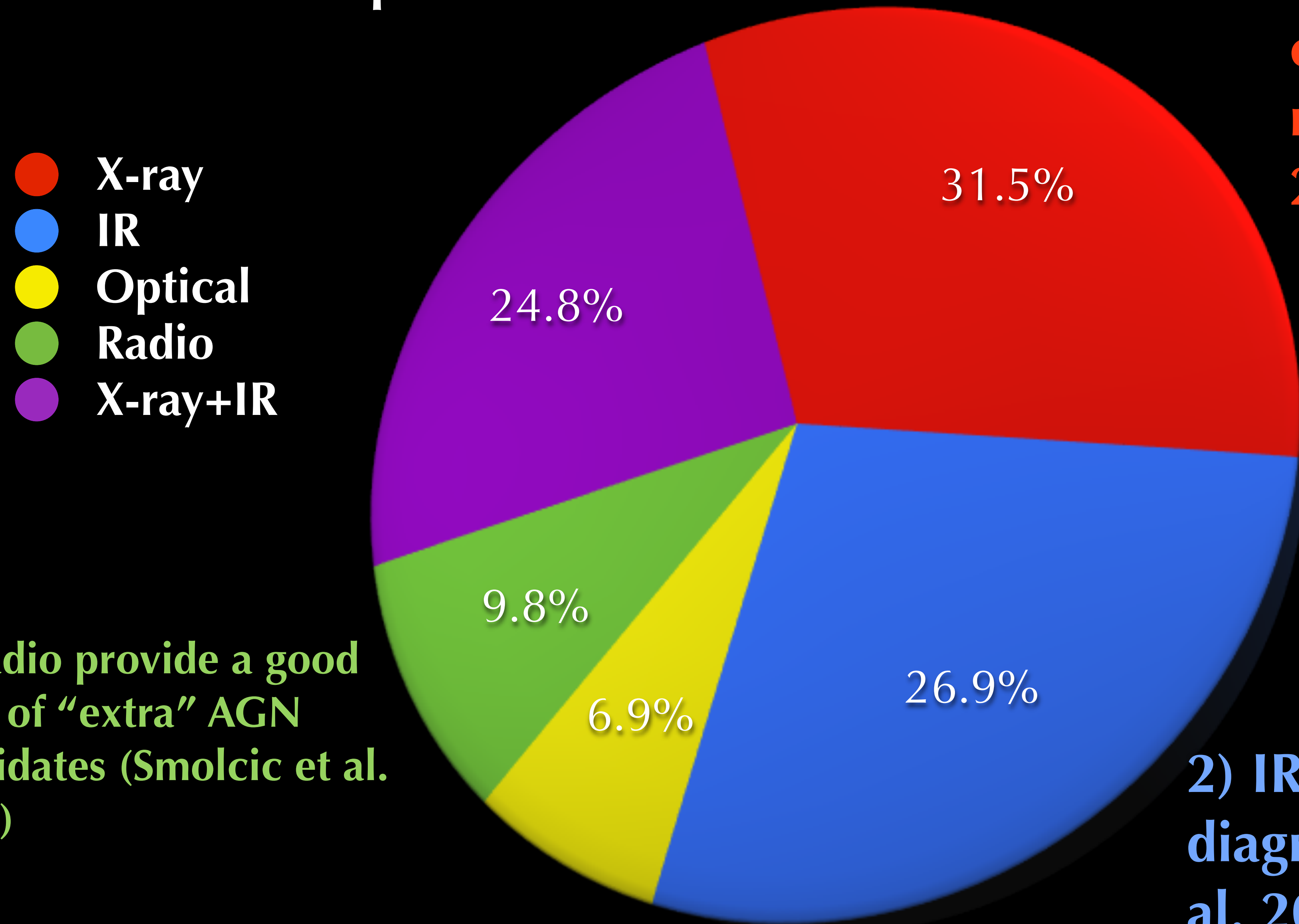
z=1.3-1.7



Comparison of AGN selection

inner 0.9 deg2 COSMOS area
deeper Chandra and optical data

1) largest contribution from X-rays (Civano et al. 2012)



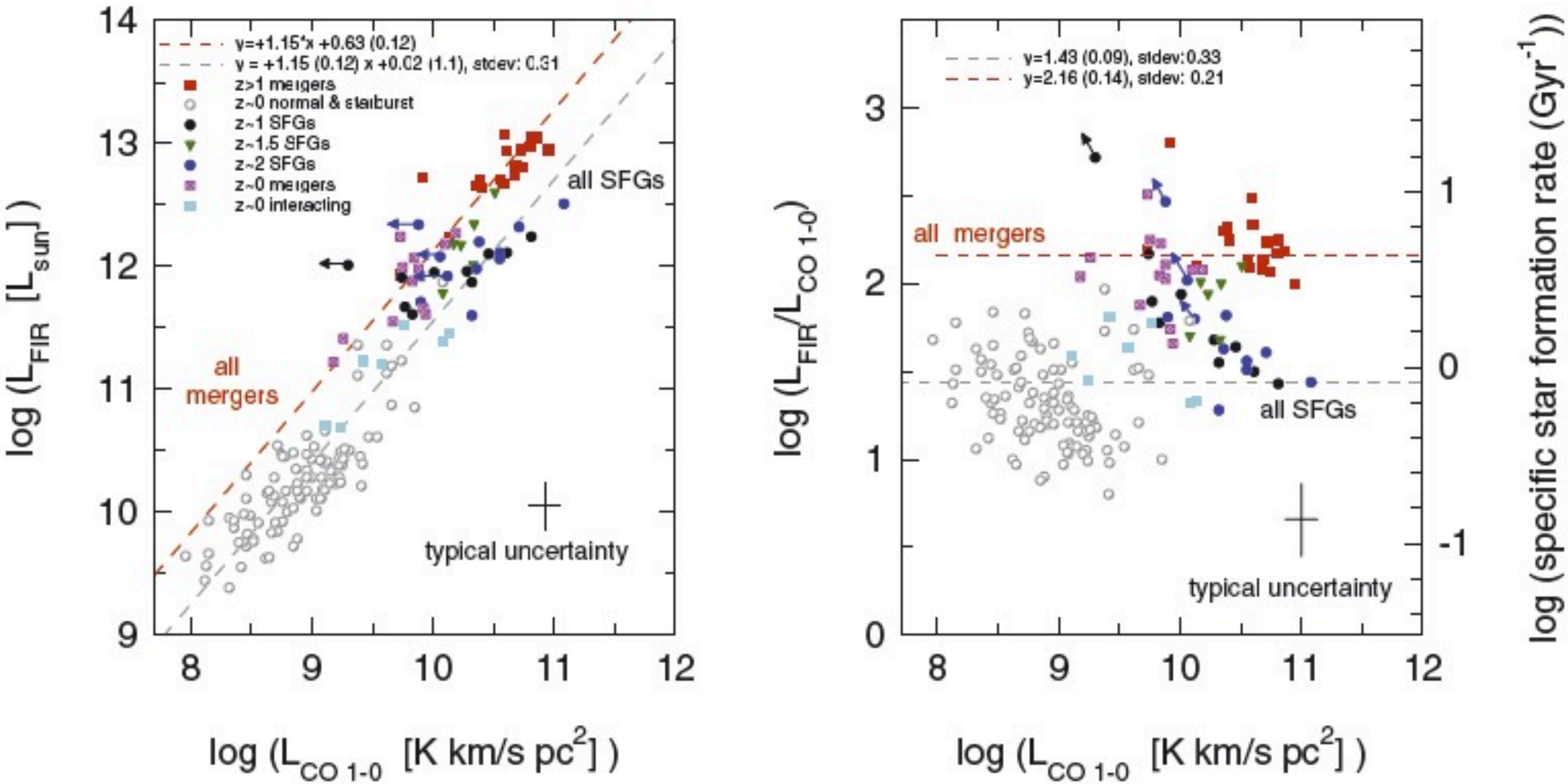
2) IRAC color-color diagrams (Donley et al. 2012)

3) Radio provide a good 10% of “extra” AGN candidates (Smolcic et al. 2008)

4) most of ONLY Optical sources are NL AGN from BPT diagrams (e..g Bongiorno et al. 2010)

relative contribution very sensitive to depth at different wavelengths..

Mergers vs. smooth accretion in mm



Two families (sequences):

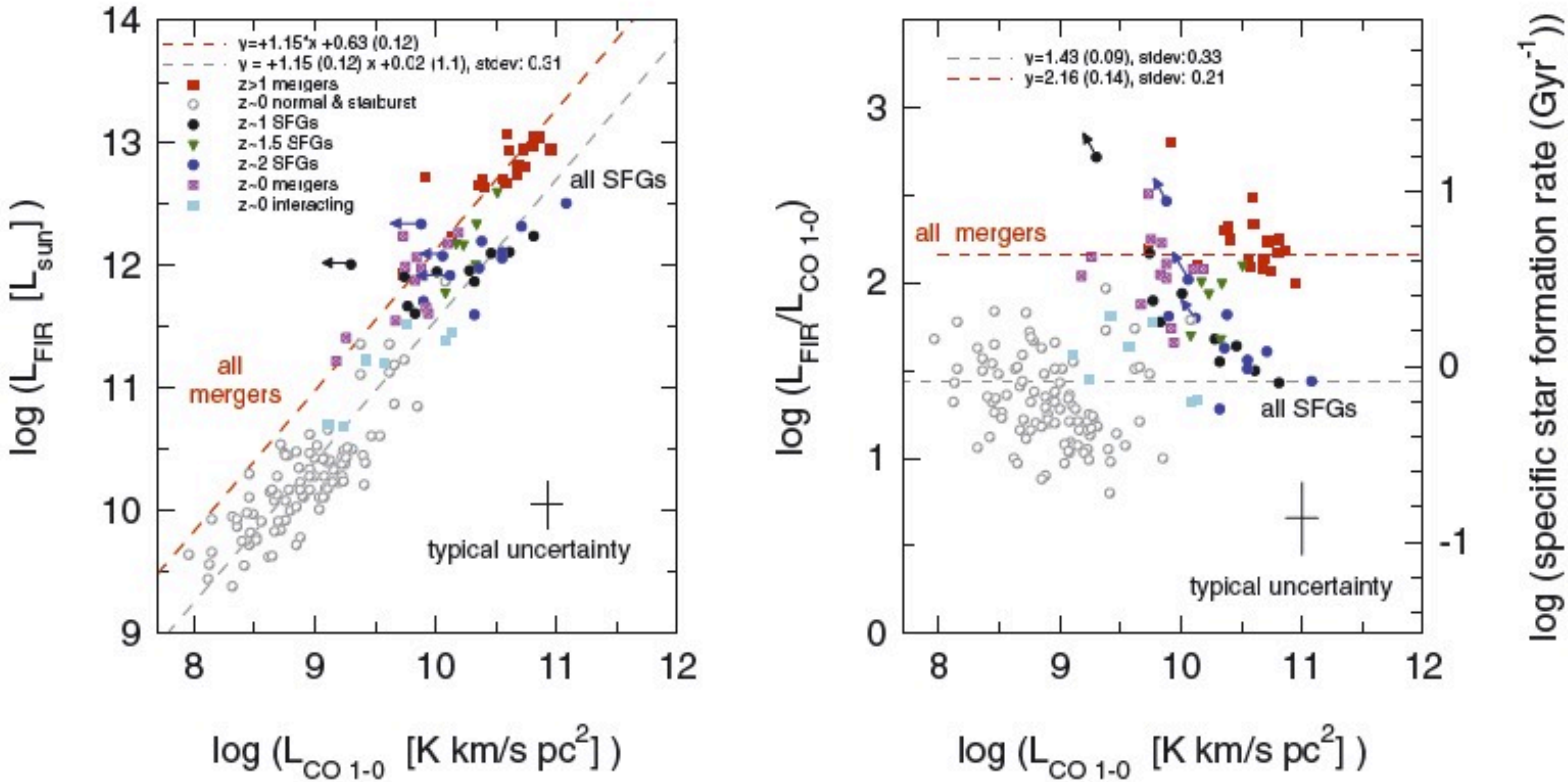
low SFE and spatially extended gas reservoirs (disks)

high SFE and compact gas reservoirs (mergers)

Genzel et al. 2010

see also Daddi et al. 2010

Mergers vs. smooth accretion in mm



Two families (sequences):

low SFE and spatially extended gas reservoirs (disks) Low-LAGN

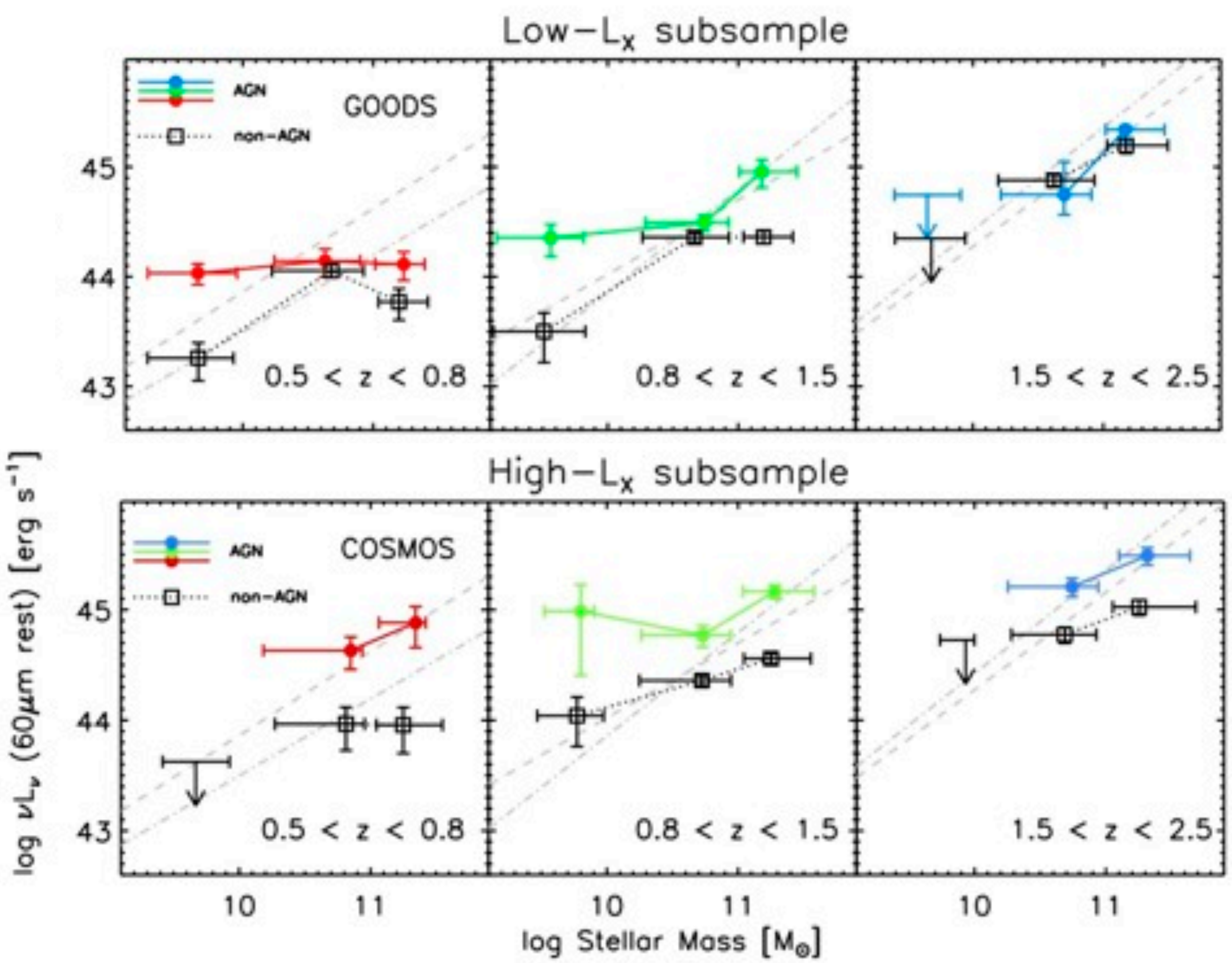
high SFE and compact gas reservoirs (mergers) high-LAGN

Genzel et al. 2010

see also Daddi et al. 2010

Enhanced SFR in AGN hosts?

Santini+2012 (GOODS & COSMOS / PEP data)



(see also Silverman+2009, Xue+2010, Mullaney+2011)

Evidence for enhancement:

- GOODS (low-Lx):
SFR in AGN hosts broadly consistent with that observed in "inactive" galaxies; (modest) enhancement observed only in low-mass samples

- COSMOS (high-Lx):
average SFR in AGN hosts ~0.6 dex higher than in "inactive" galaxies, at all z/masses

Enhancement is measured.... but this does not mean that AGN do preferentially live in strong starbursts.

Weighted average of detections and non-detections --> PACS detection rate is higher for AGN than non-AGN