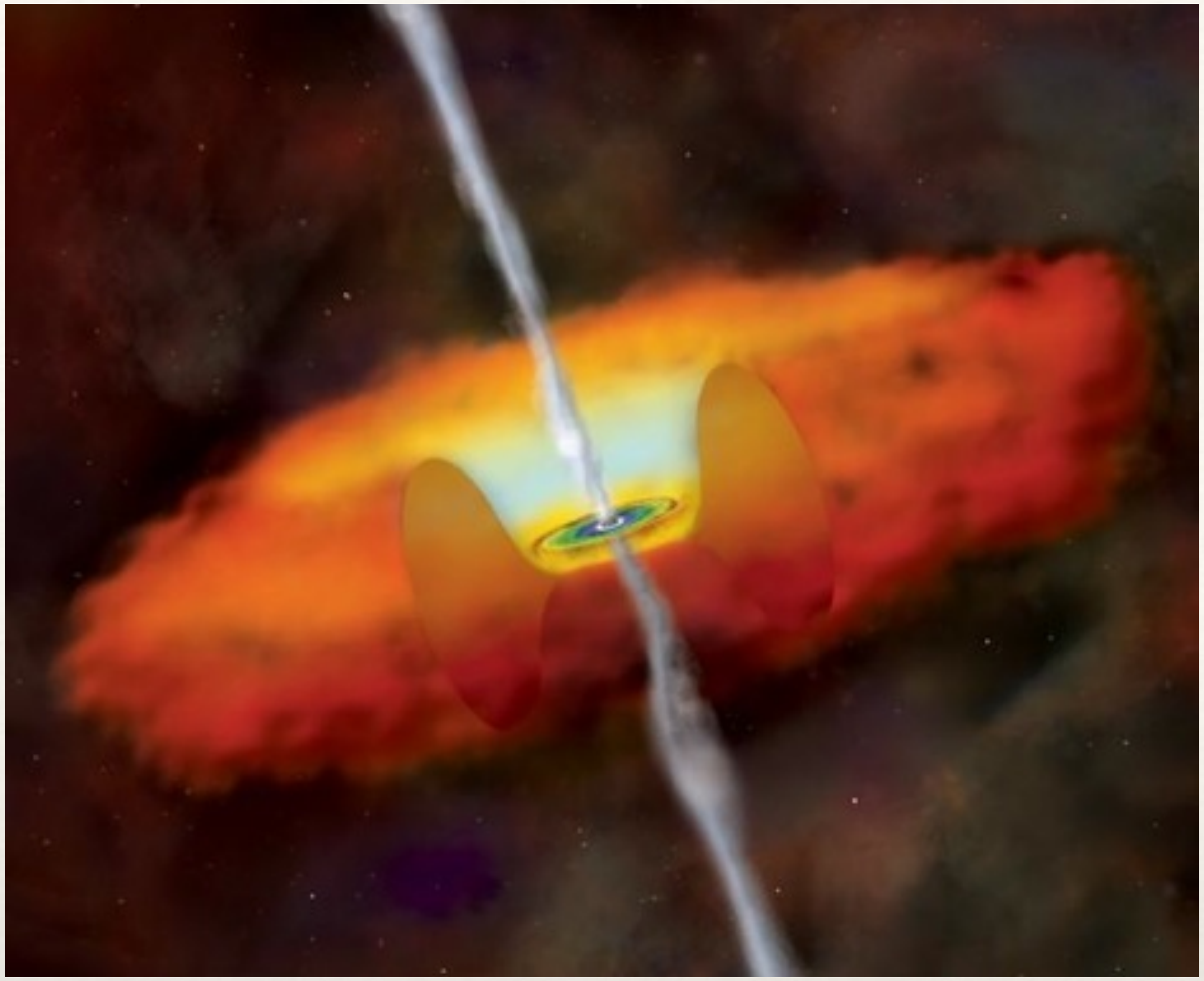


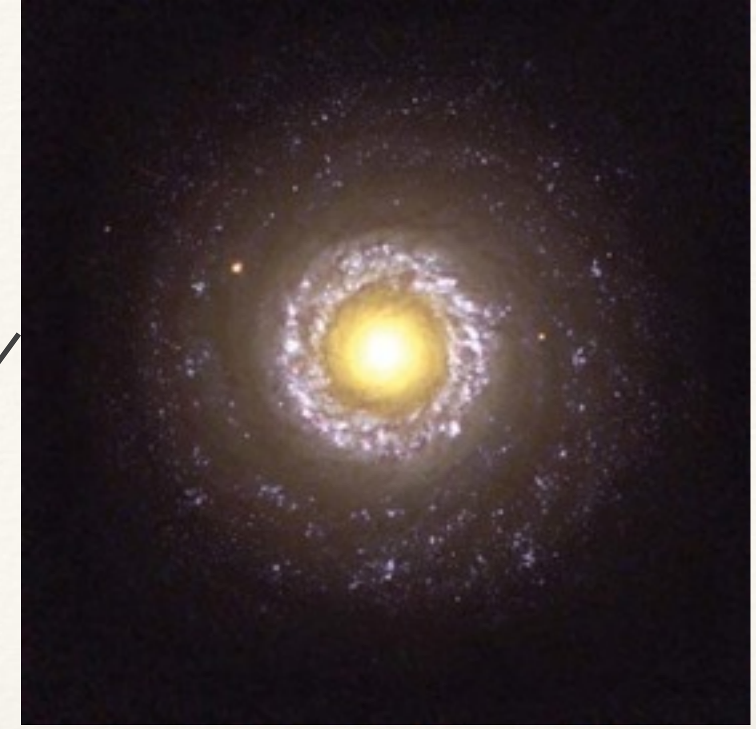
AGN vs SF 2014 Durham University

Obscuration and Star formation in Luminous Quasars

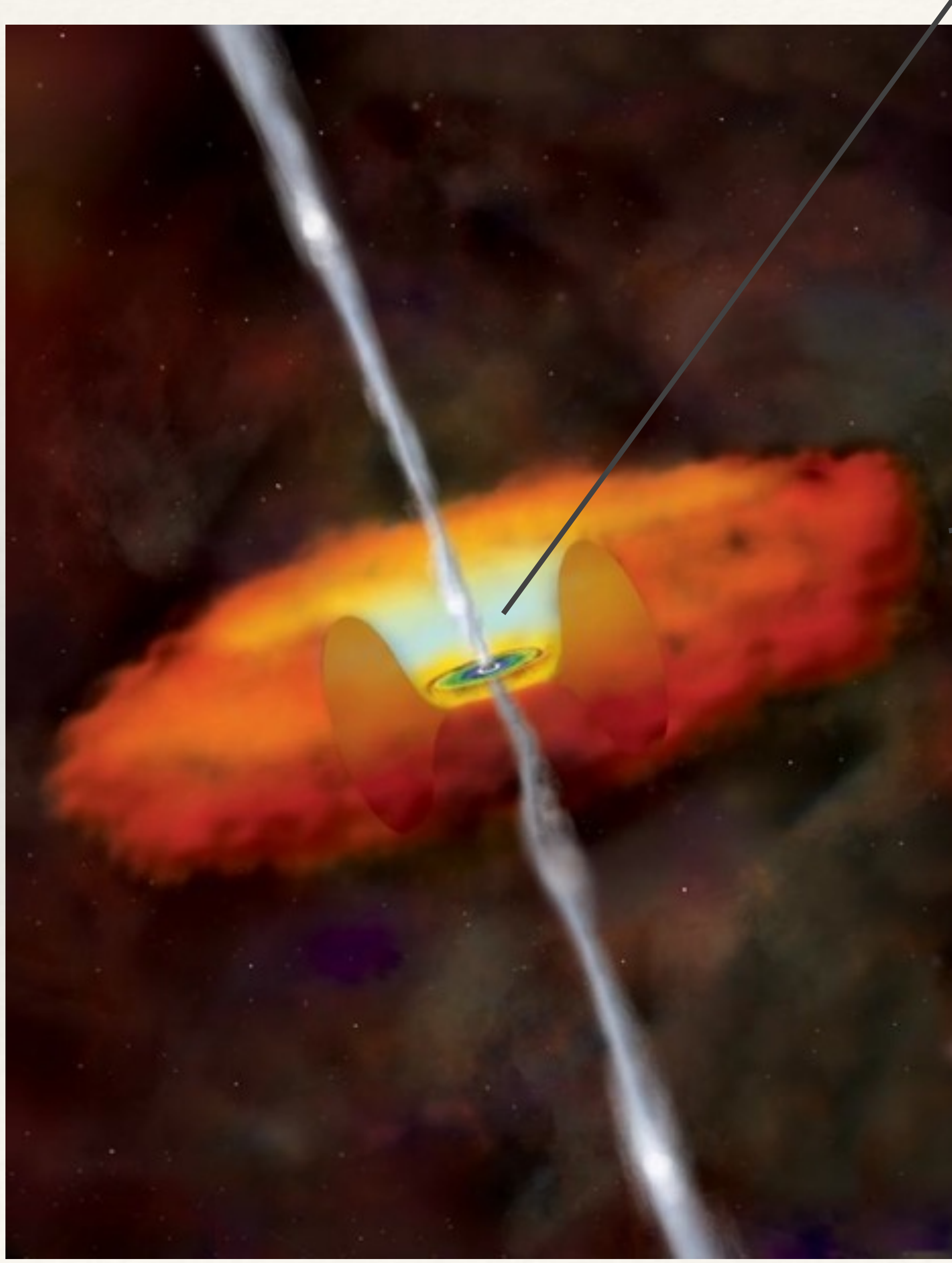
Chien-Ting Chen
Dartmouth College

In collaboration with: Ryan C. Hickox, Stacey Alberts, David M. Alexander, Roberto Assef, Michael J.~I. Brown, Agnese Del Moro, William F. Forman, Andrew D. Goulding, Chris Harrison, Christine Jones, Stephen S. Murray,Alexandra Pope, Manolis Rovilos and the Boötes Collaboration

AGN types and the unification model



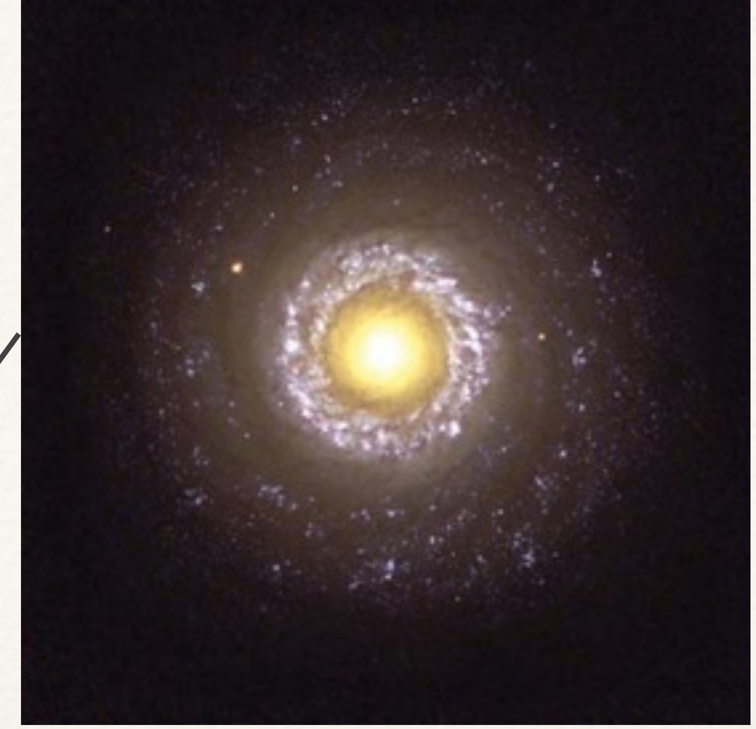
Type 1



Type 2

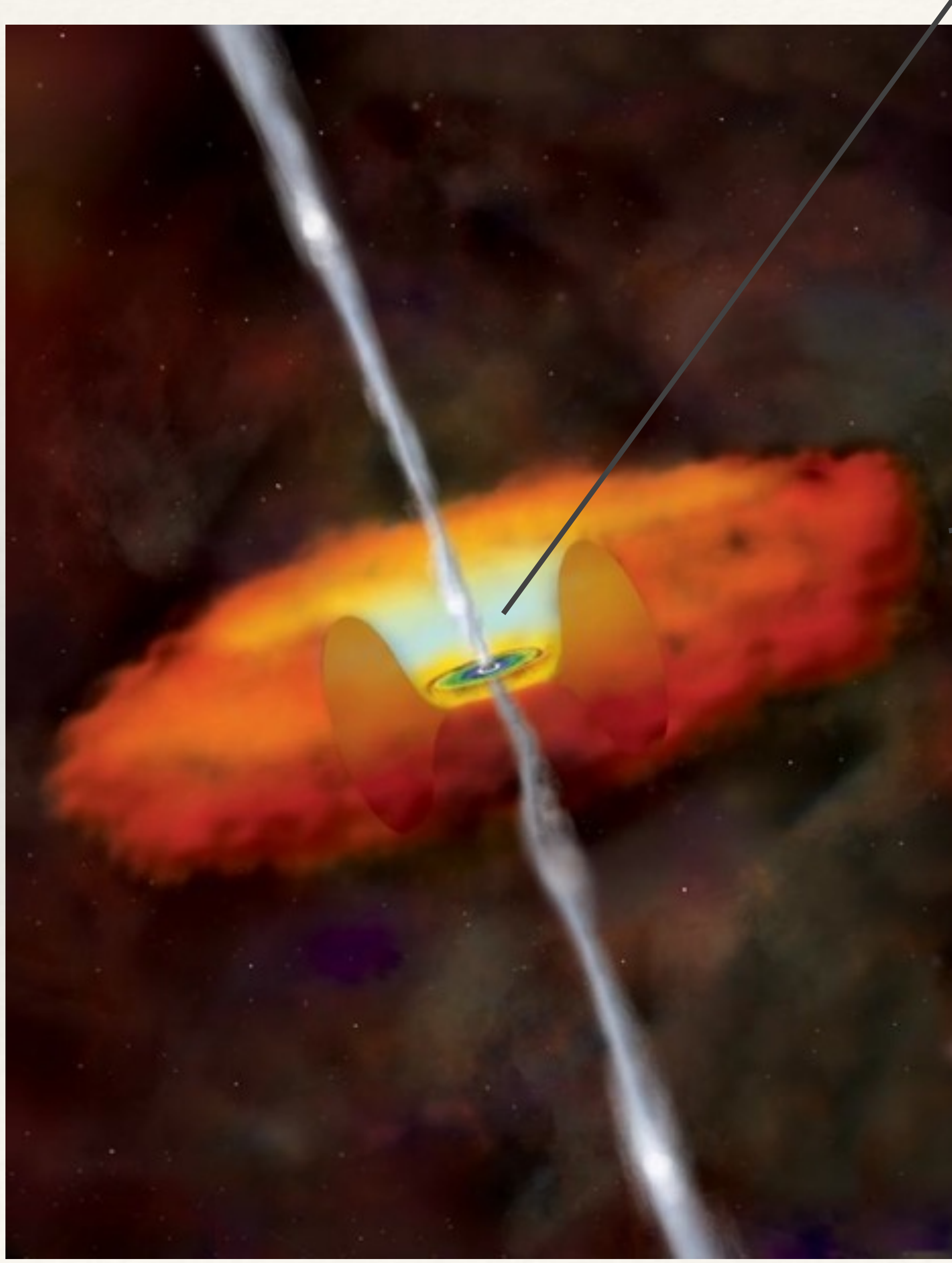
Antonuucci 1993, Urry & Padovani 1995

AGN types and the unification model



Type 1

Type 2

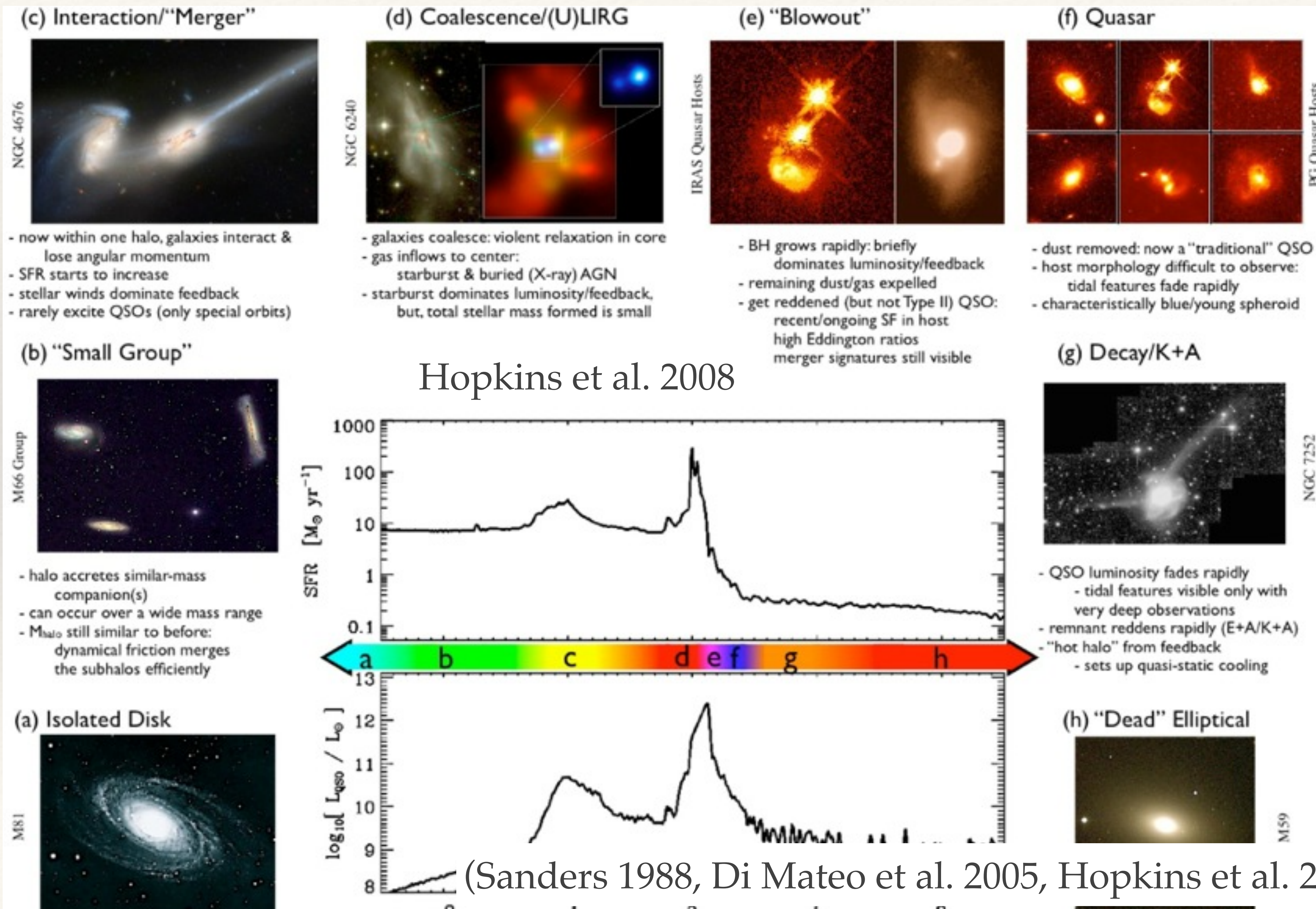


According to the AGN unification model, there should not be any difference in the properties of their host galaxies

Antonuucci 1993, Urry & Padovani 1995

The AGNvsSF point of view

Merger/Starburst | ULIRG/ obscured quasar | ``SF quenching” AGN outflow | unobscured quasar



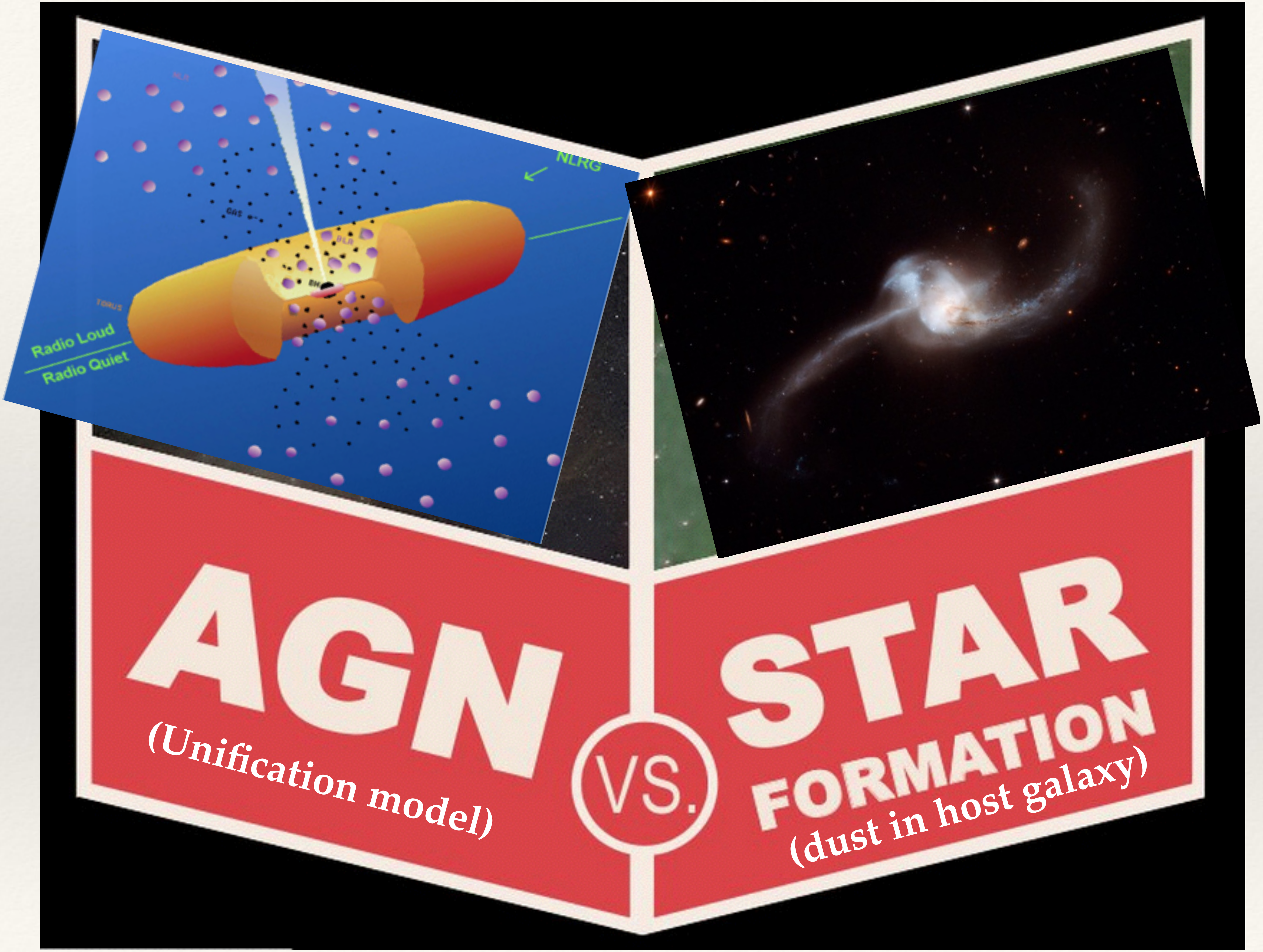
Hopkins et al. 2008

(Sanders 1988, Di Mateo et al. 2005, Hopkins et al. 2008)

Is the origin of obscuration in
quasars different than that in Seyferts?

A simple test:
the star formation rates in unobscured and obscured quasars

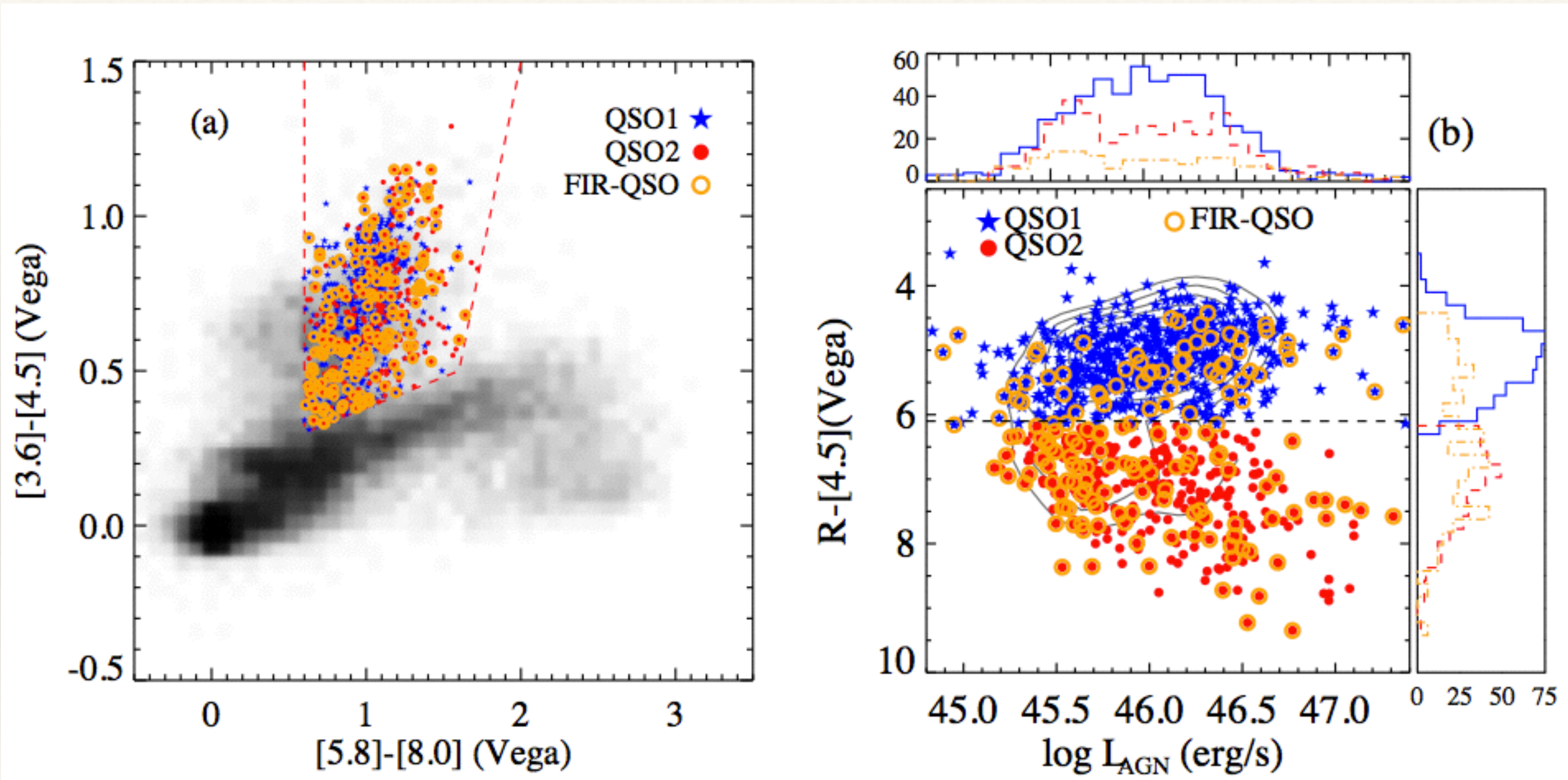

AGN
VS.
STAR
FORMATION



NLRG
Radio Loud
Radio Quiet
AGN
(Unification model)
VS.
STAR
FORMATION
(dust in host galaxy)

Mid-IR selected quasars in Boötes

Stern+ ’05, Hickox+ ’07, ’11

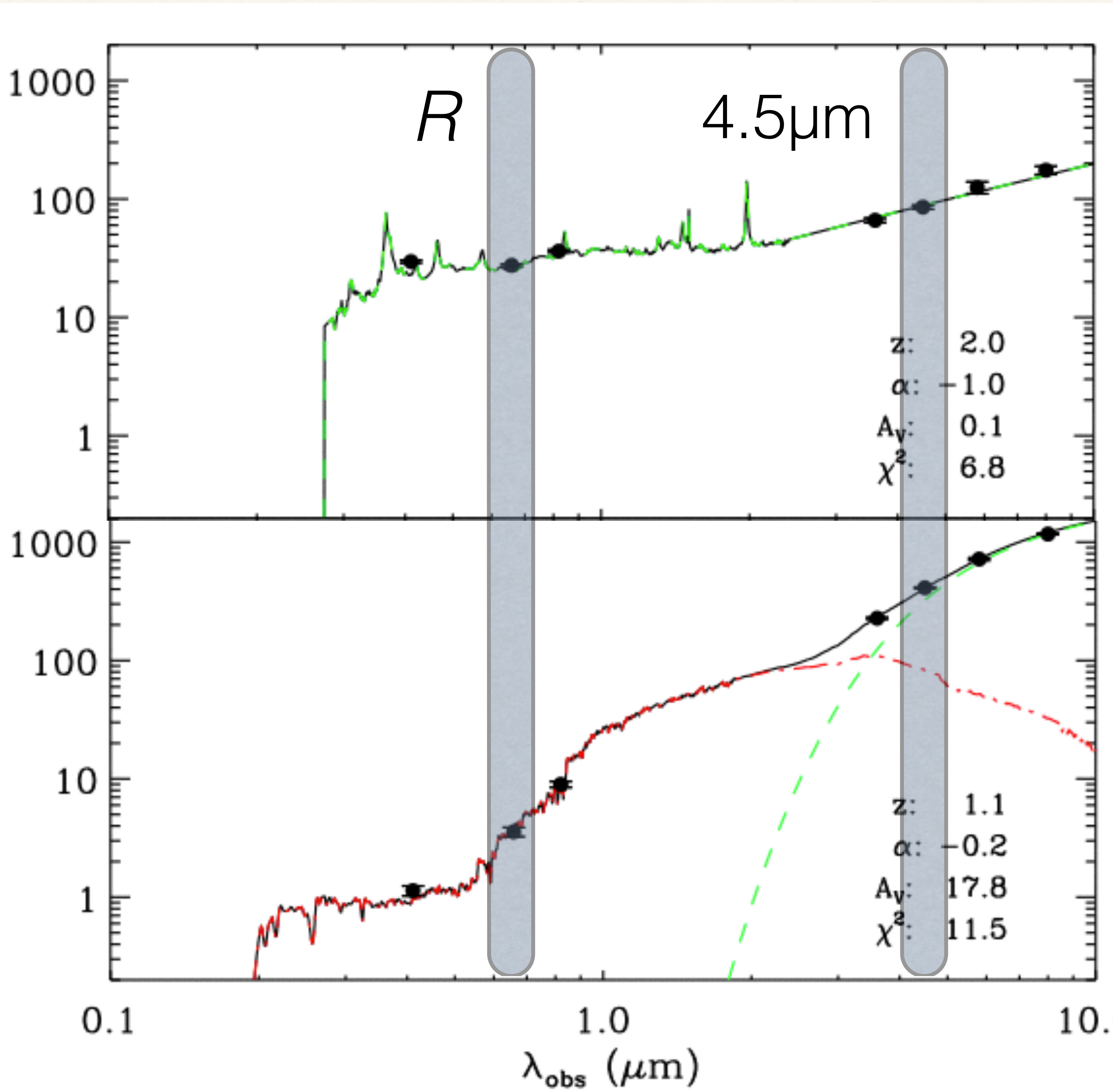


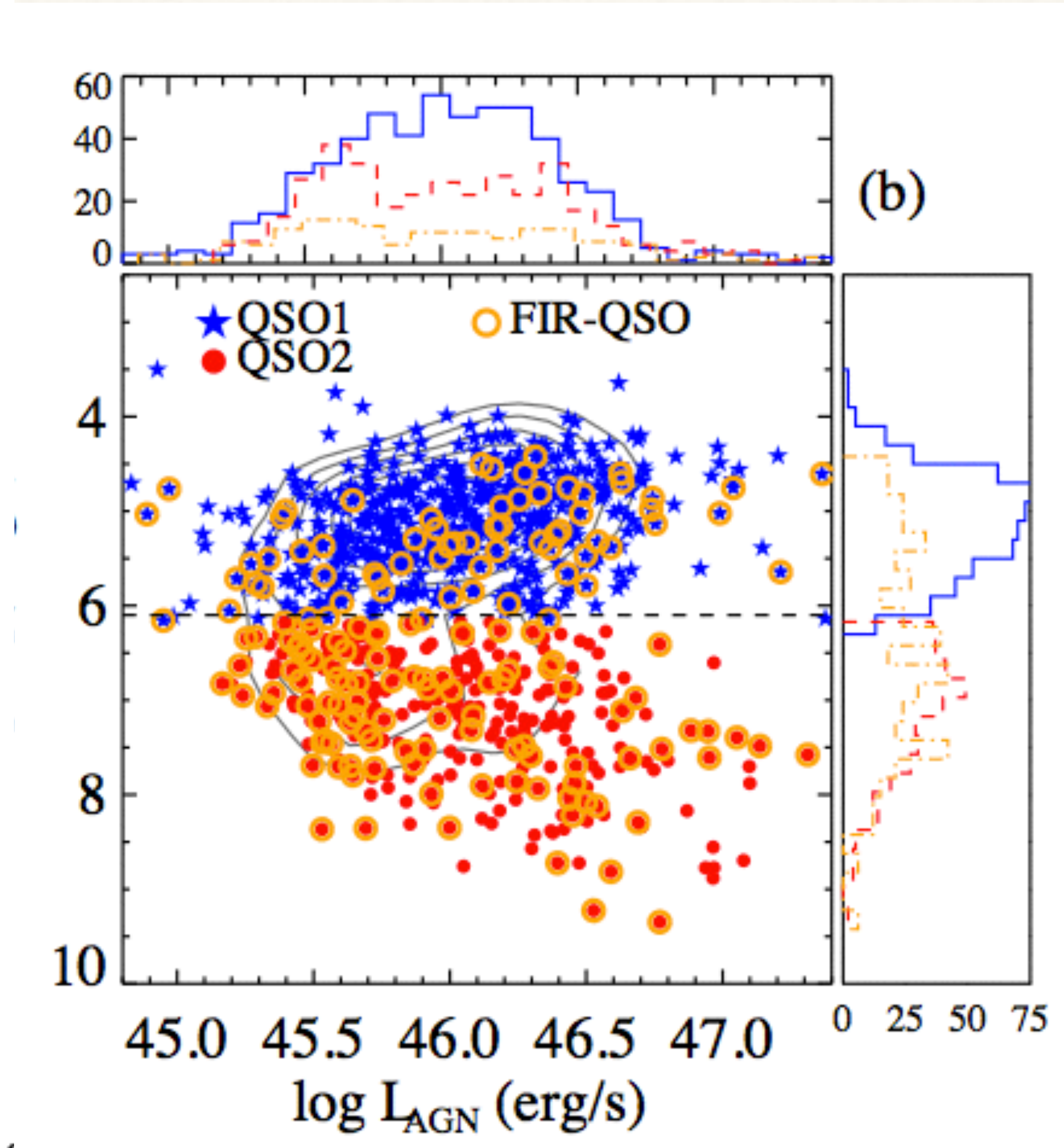
563 QSO1s(type I), 361 QSO2s (obscured), 0.7<z<1.8

log Lbol > 45 [erg/s]

Mid-IR selected quasars in Boötes

Stern+ '05, Hickox+ '07, '11

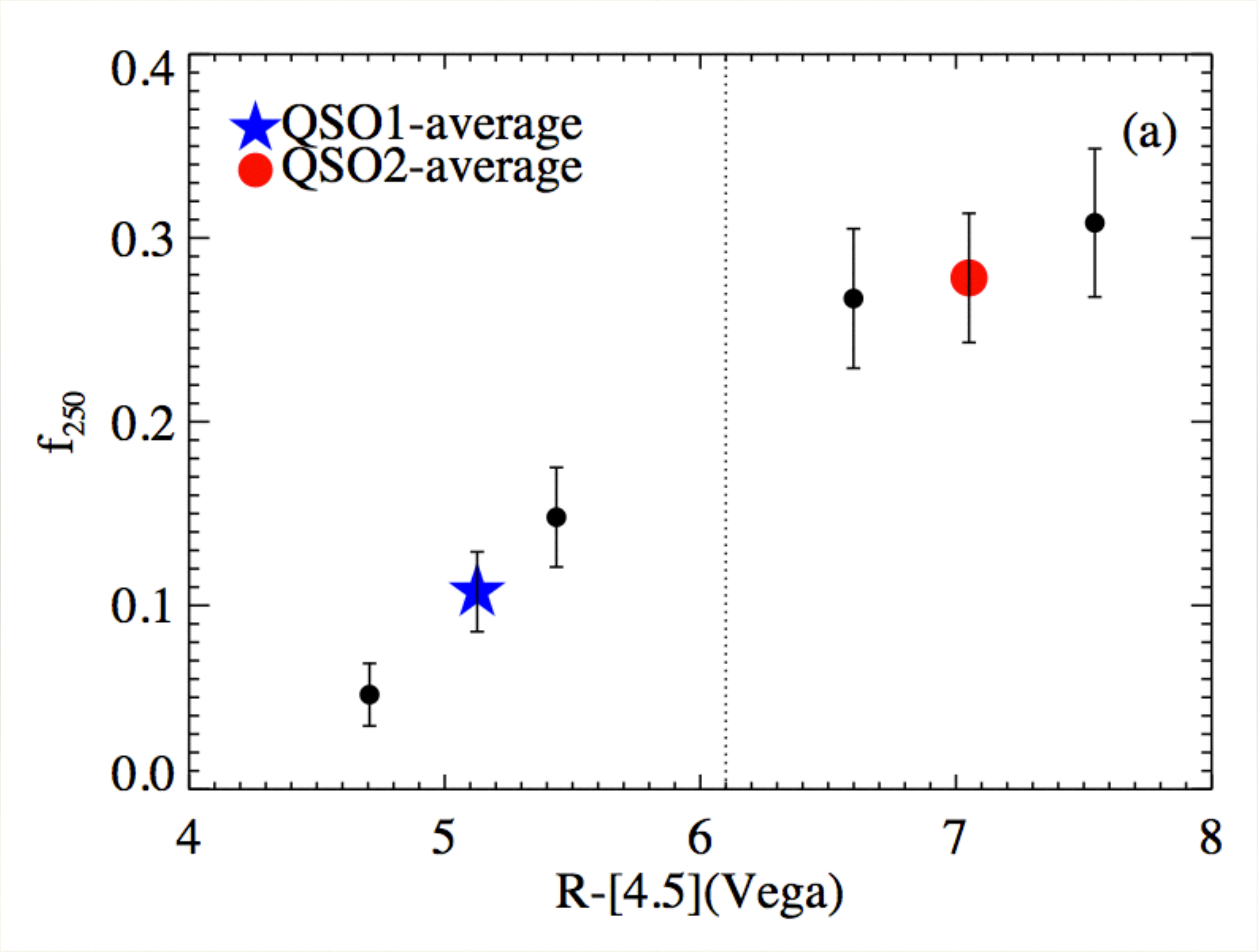


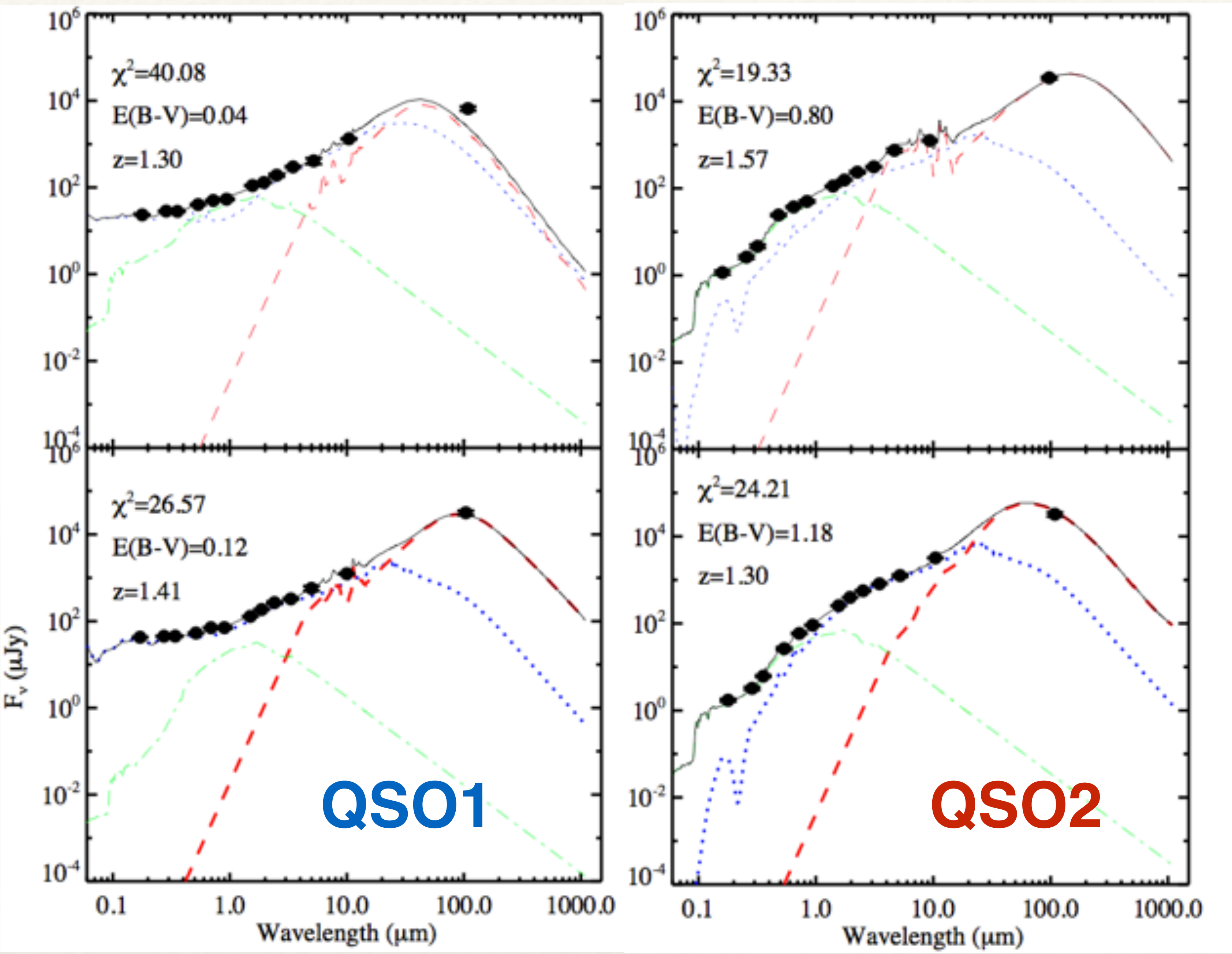


2s (obscured), 0.7<z<1.8

log Lbol > 45 [erg/s]

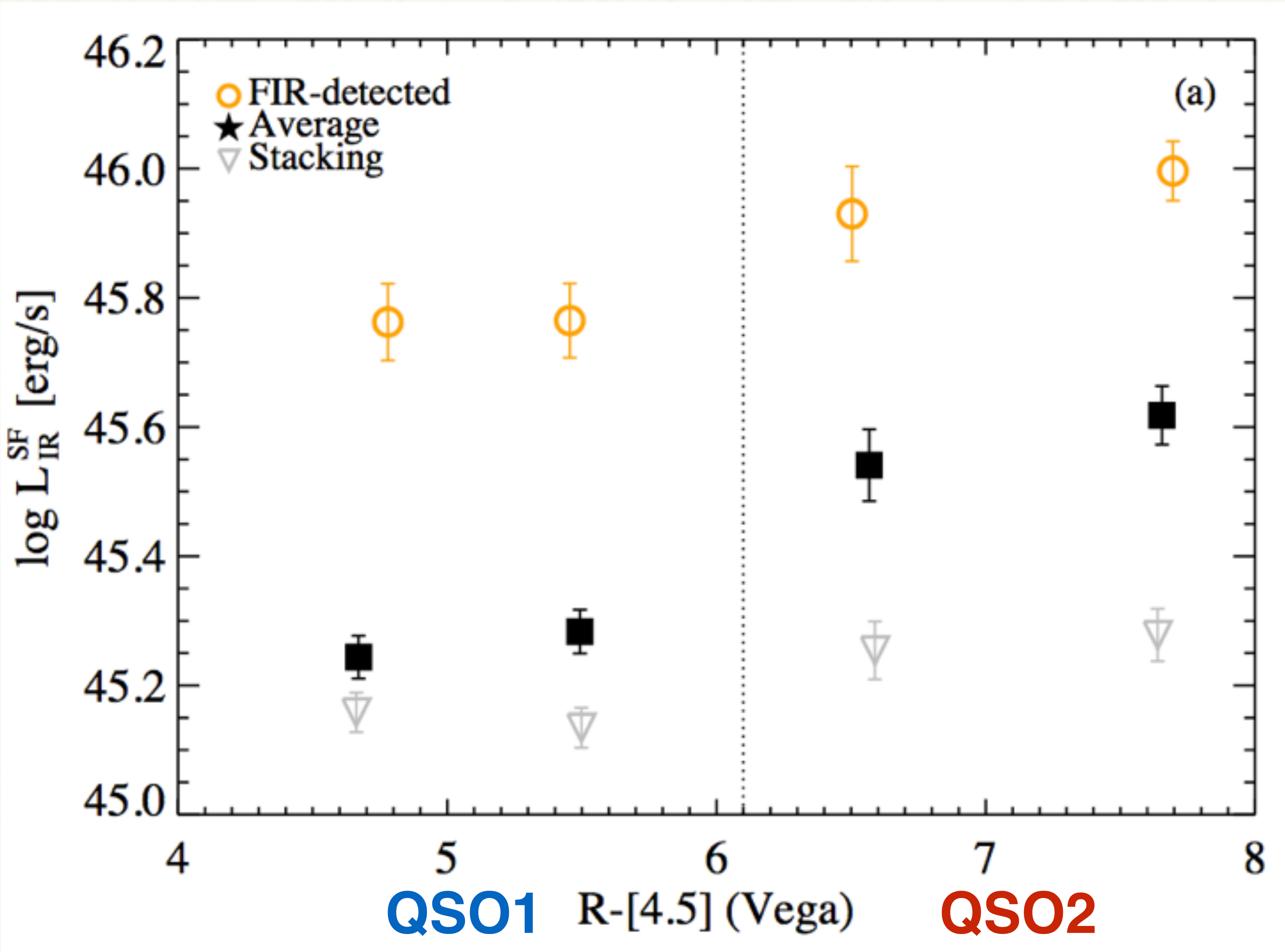
Obscured quasars have higher FIR detection fraction (SPIRE 250 micron)





Examples of SED fitting for QSO1s and QSO2s. Blue line: AGN; red line: starburst; green line: stellar population

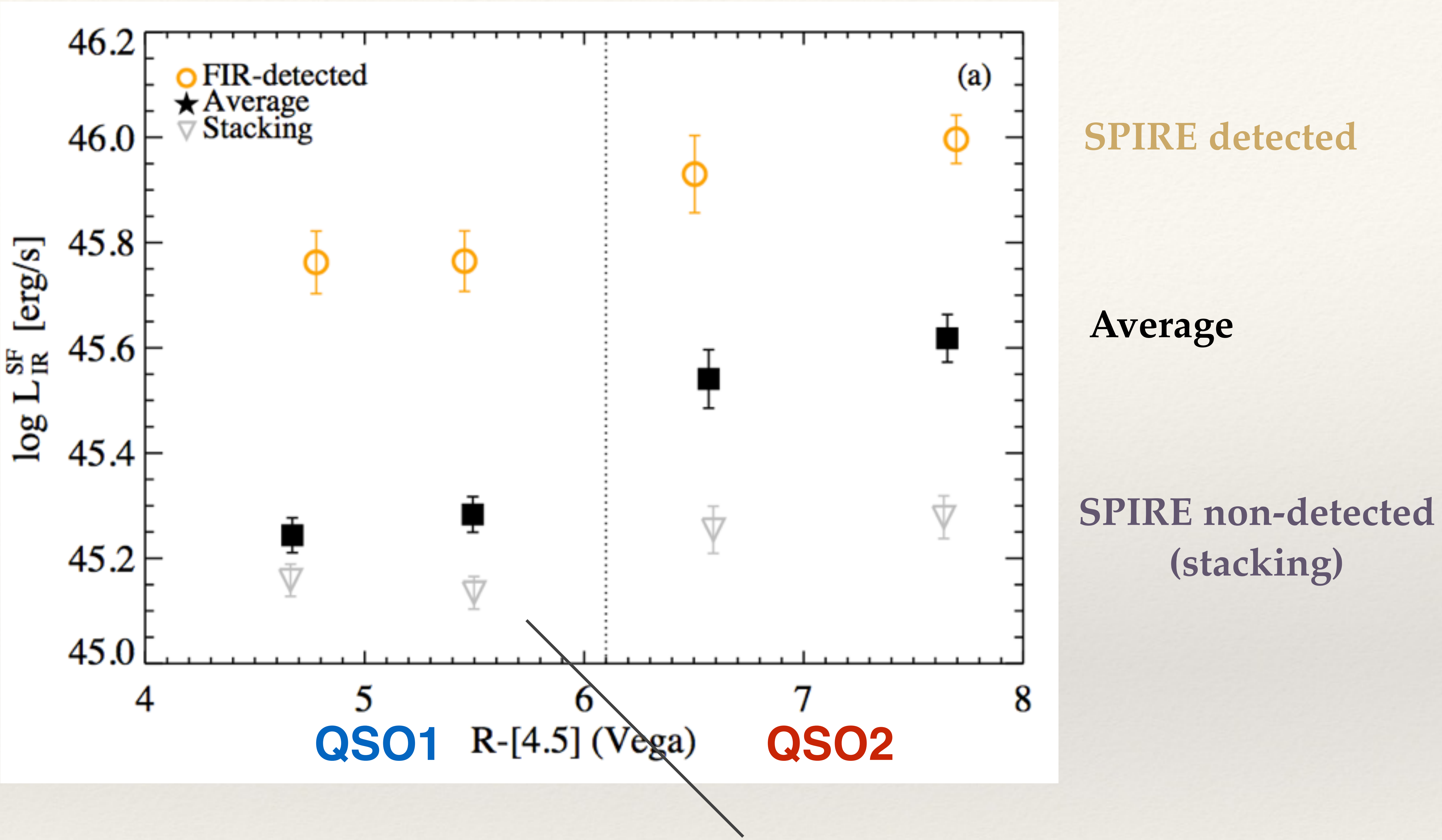
- 3 empirical stellar population templates (Assef +2008)
- 171 starburst templates (Cary & Elbaz 2001, Dale & Helou 2002, Kirkpatrick +2012)
- AGN templates: Assef+ 2010, Mullaney+ 2011, Netzer+ 2007 (corrected for host galaxy contamination!)
- Draine 2003 Extinction law (on the AGN templates only)



SPIRE detected

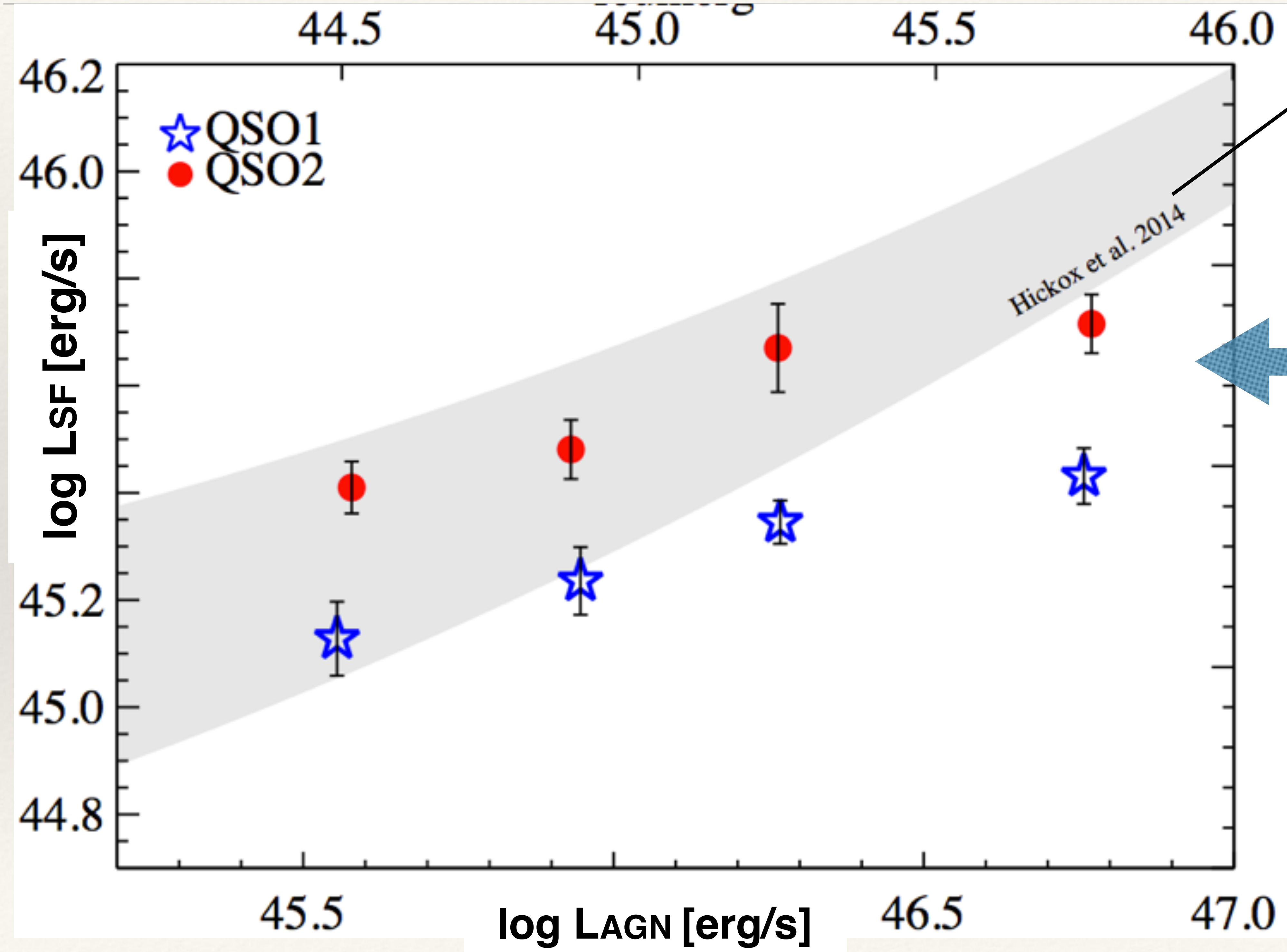
Average

SPIRE non-detected
(stacking)



For individual QSOs without direct SPIRE detections, the stacked fluxes are higher than the best-fitting AGN SEDs by an average of 1.31 dex

L_{SF}-L_{AGN} correlation for QSO1s and QSO2s



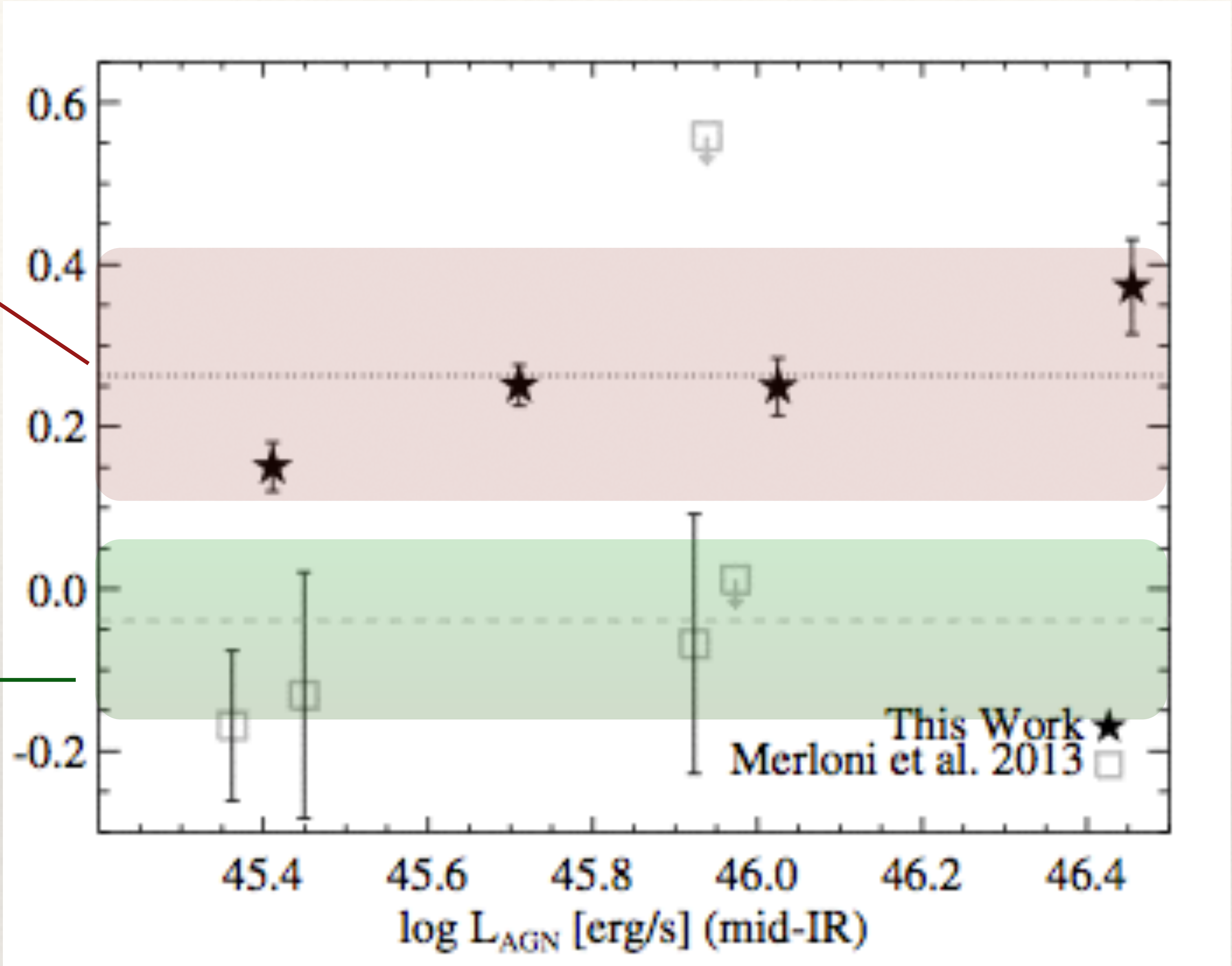
Hickox+2014 toy model

L_{SF}(QSO2)-L_{SF}(QSO1) >0.3 dex

Chen+ 2014 in prep

Mid-IR AGN
(this work)

SFR (type2)/
SFR(type 1)



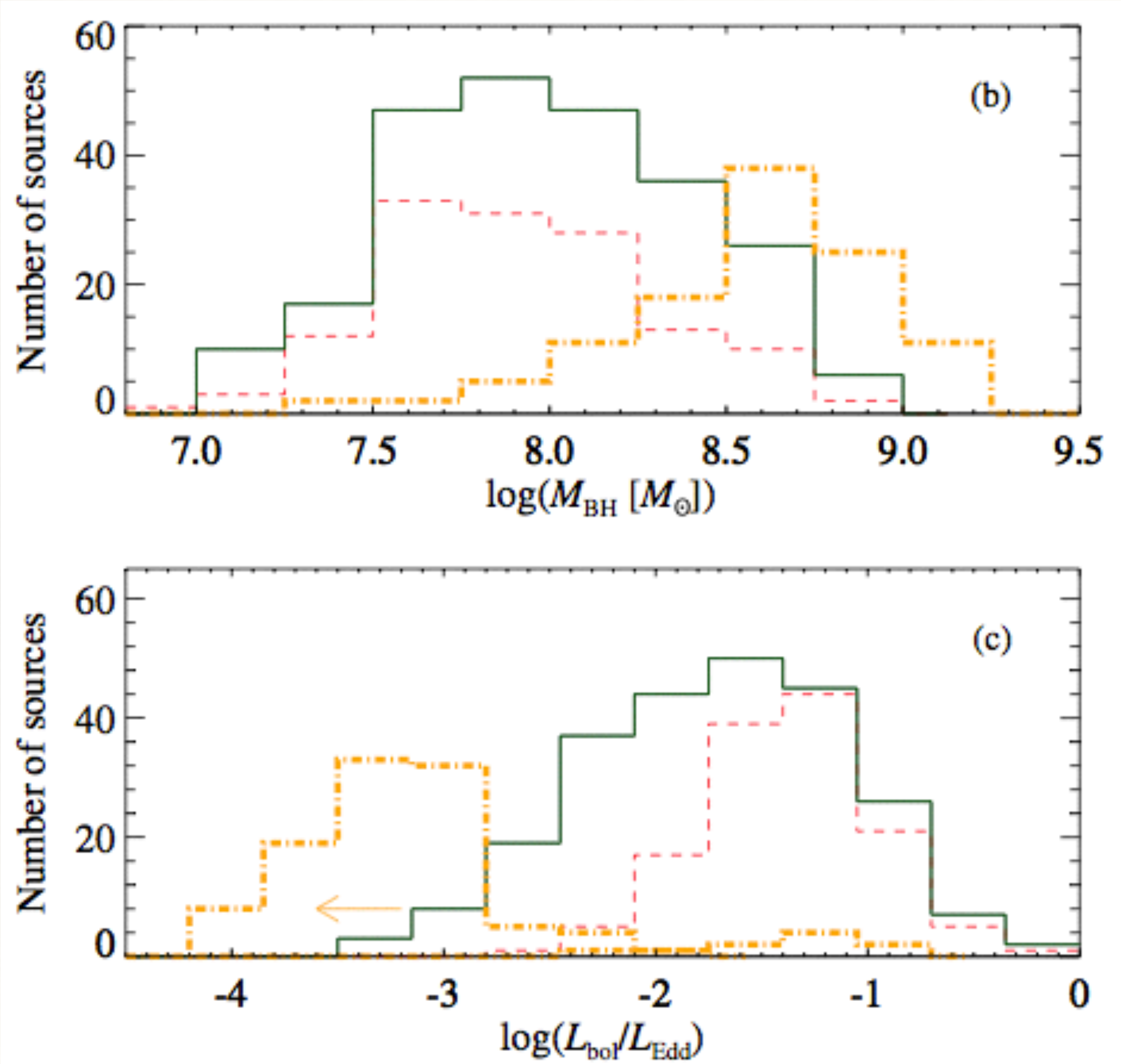
AGN accretion luminosity

X-ray AGN
(Merloni+ 2014)

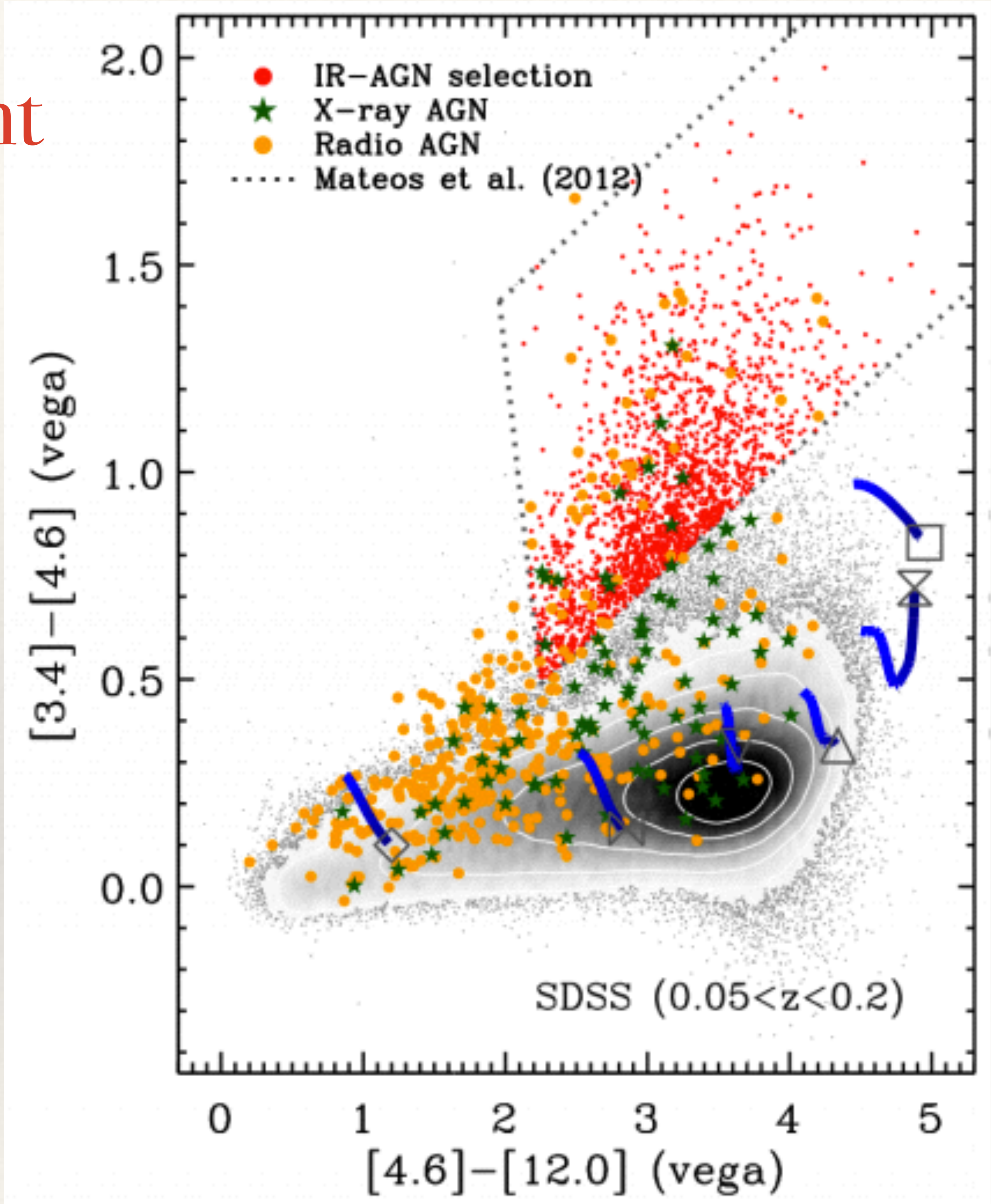
Also: host galaxy SFR does not depend on the gas column density measured from X-ray e.g. Rovilos+ 2012, Rosario+ 2012

Chen+ 2014 in prep

AGN selected in different wavelengths represent different populations

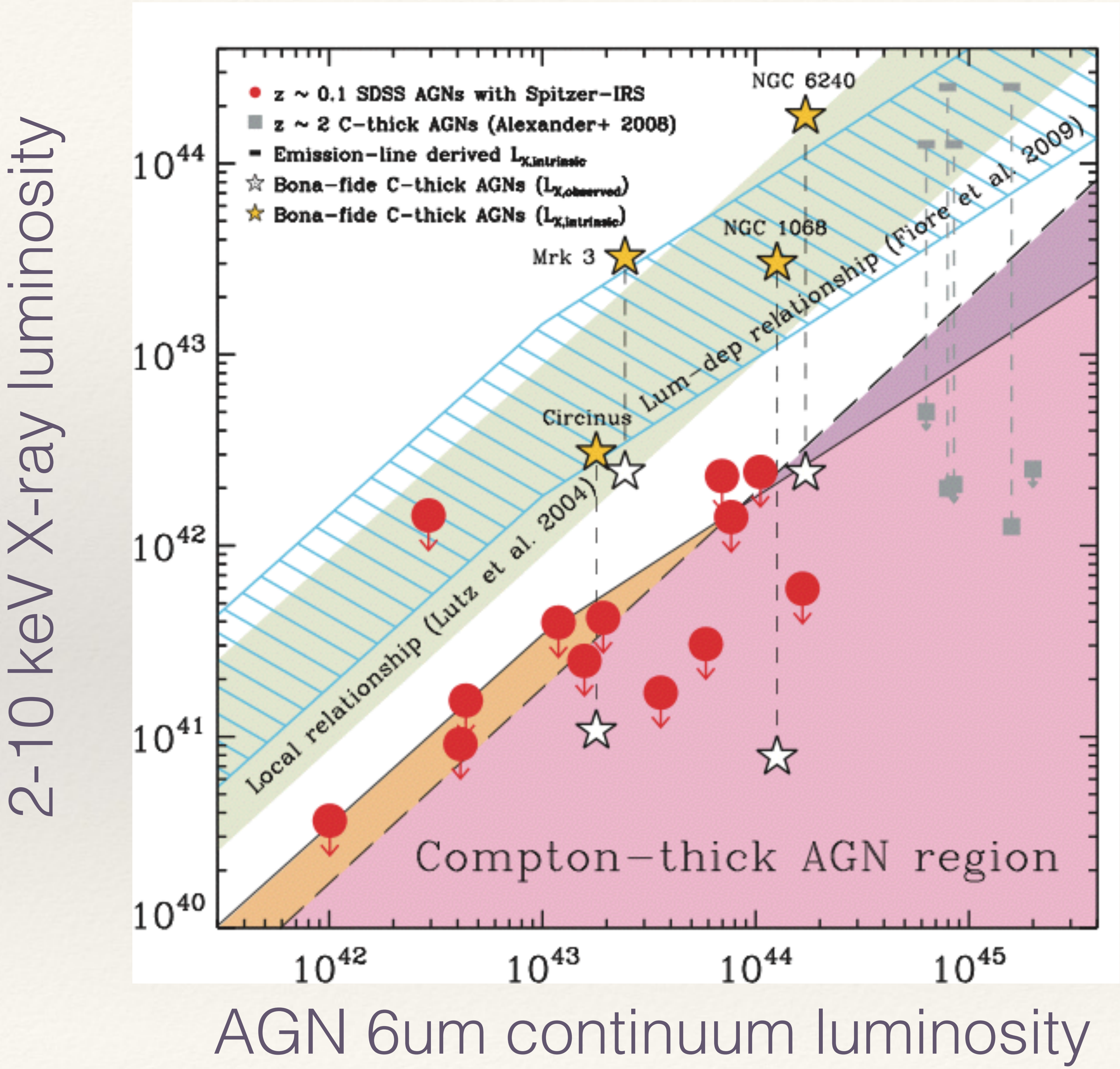


Hickox et al. 2009

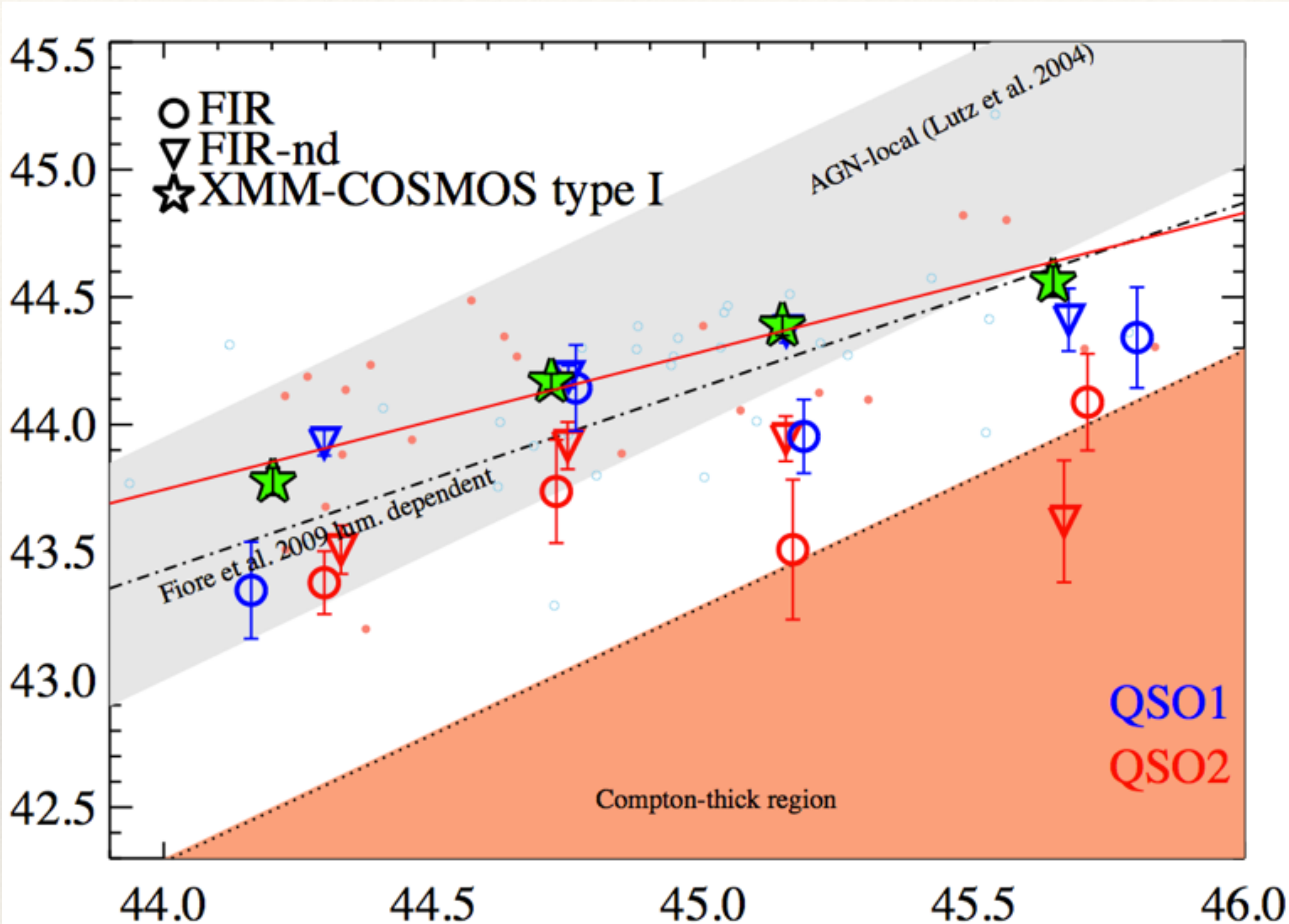


Goulding et al. 2014

What is the ``intrinsic'' AGN accretion luminosity?



e.g.
Alexander+ 2008
Gandhi+ 2009
Goulding+ 2010
Rovilos+ 2013



2-10 keV X-ray luminosity

AGN 6um continuum luminosity

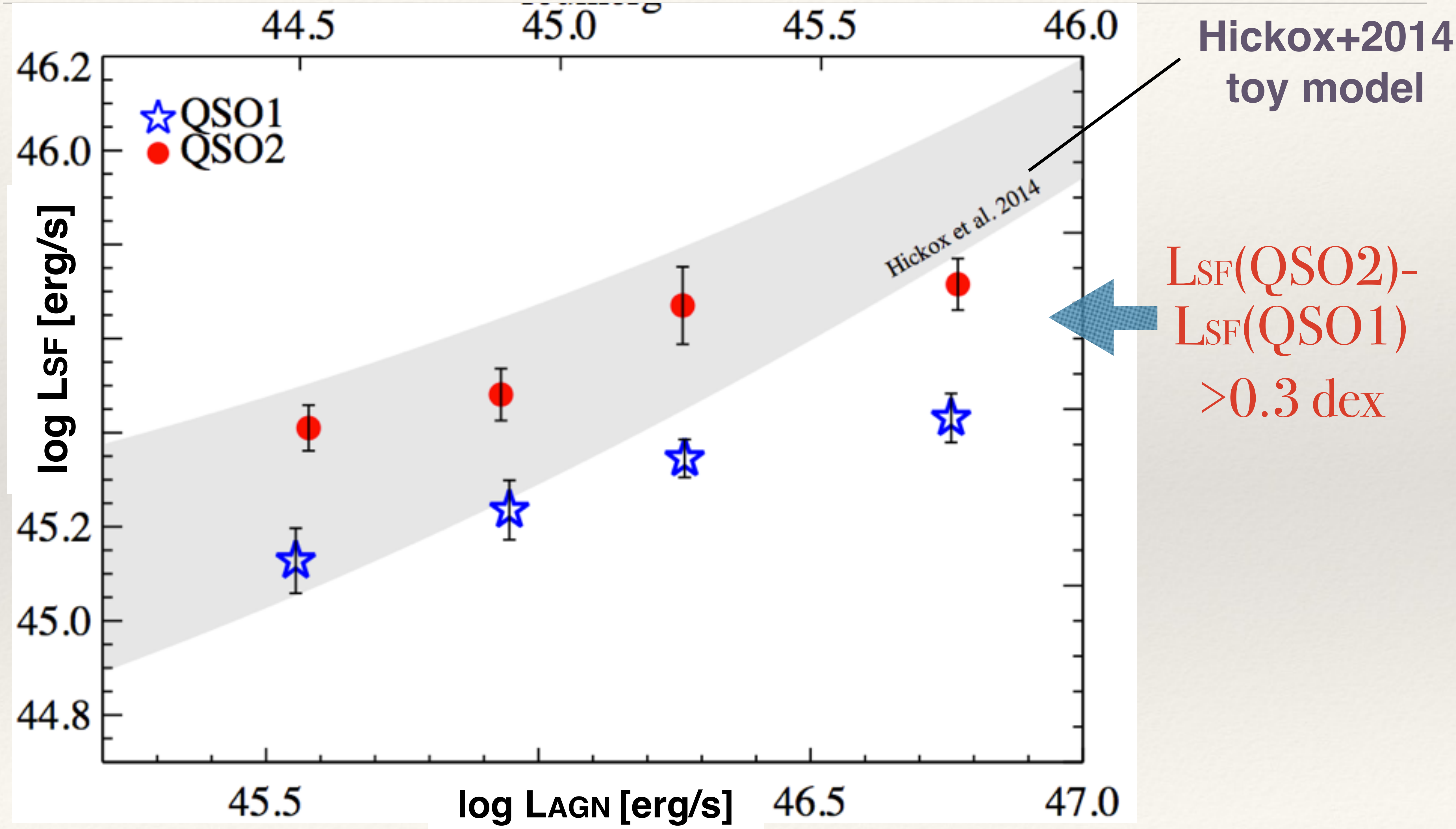
(All luminous quasars here)

Fiore+ 2009

Boötes
XMM-COSMOS
Type I QSO

Chen+ 2014, in prep
Lusso+ 2010
Elvis+ 2012

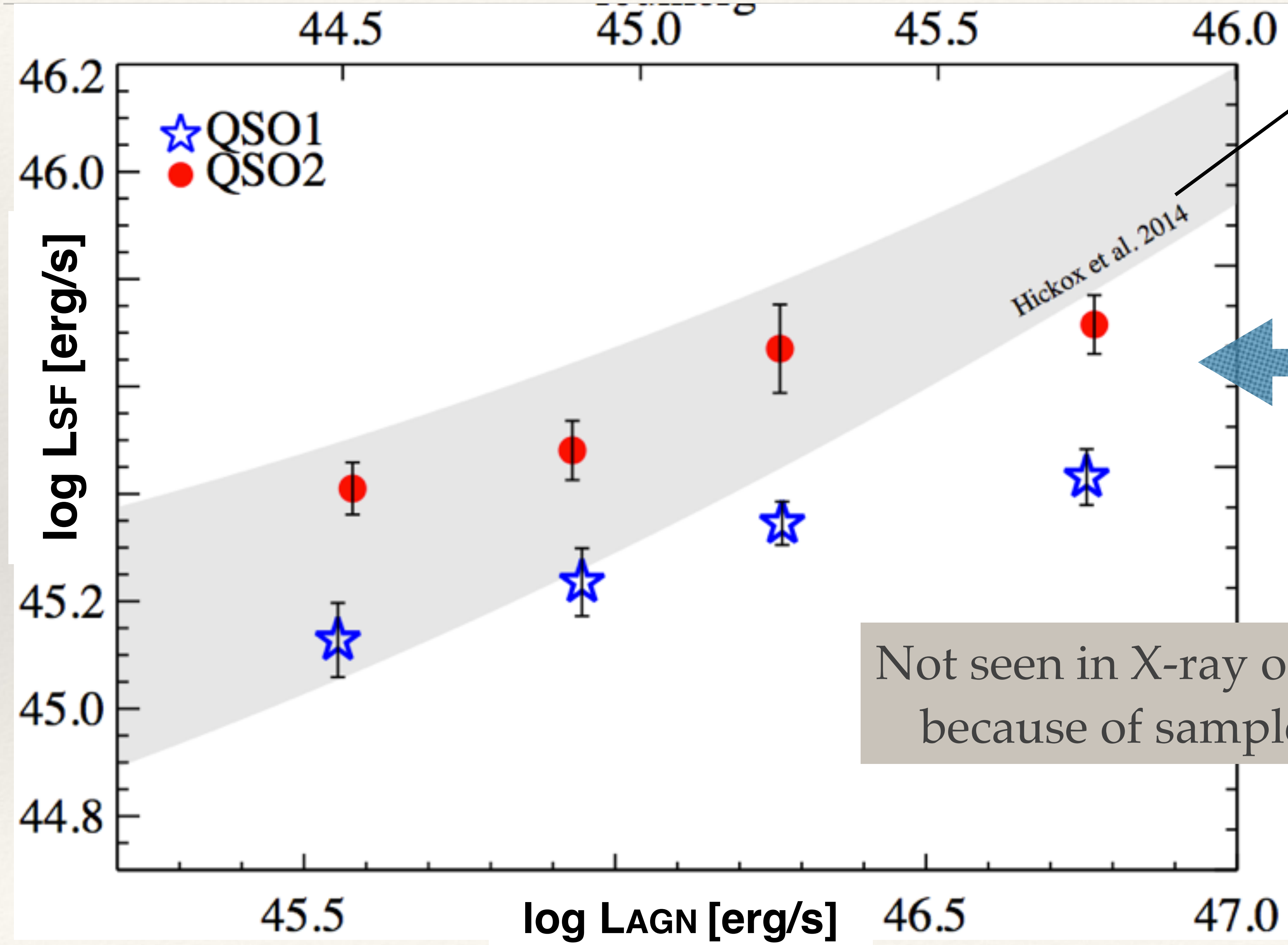
LSF-LAGN correlation for QSO1s and QSO2s



Chen+ 2014 in prep

AGN accretion

LSF-LAGN correlation for QSO1s and QSO2s



Hickox+2014 toy model

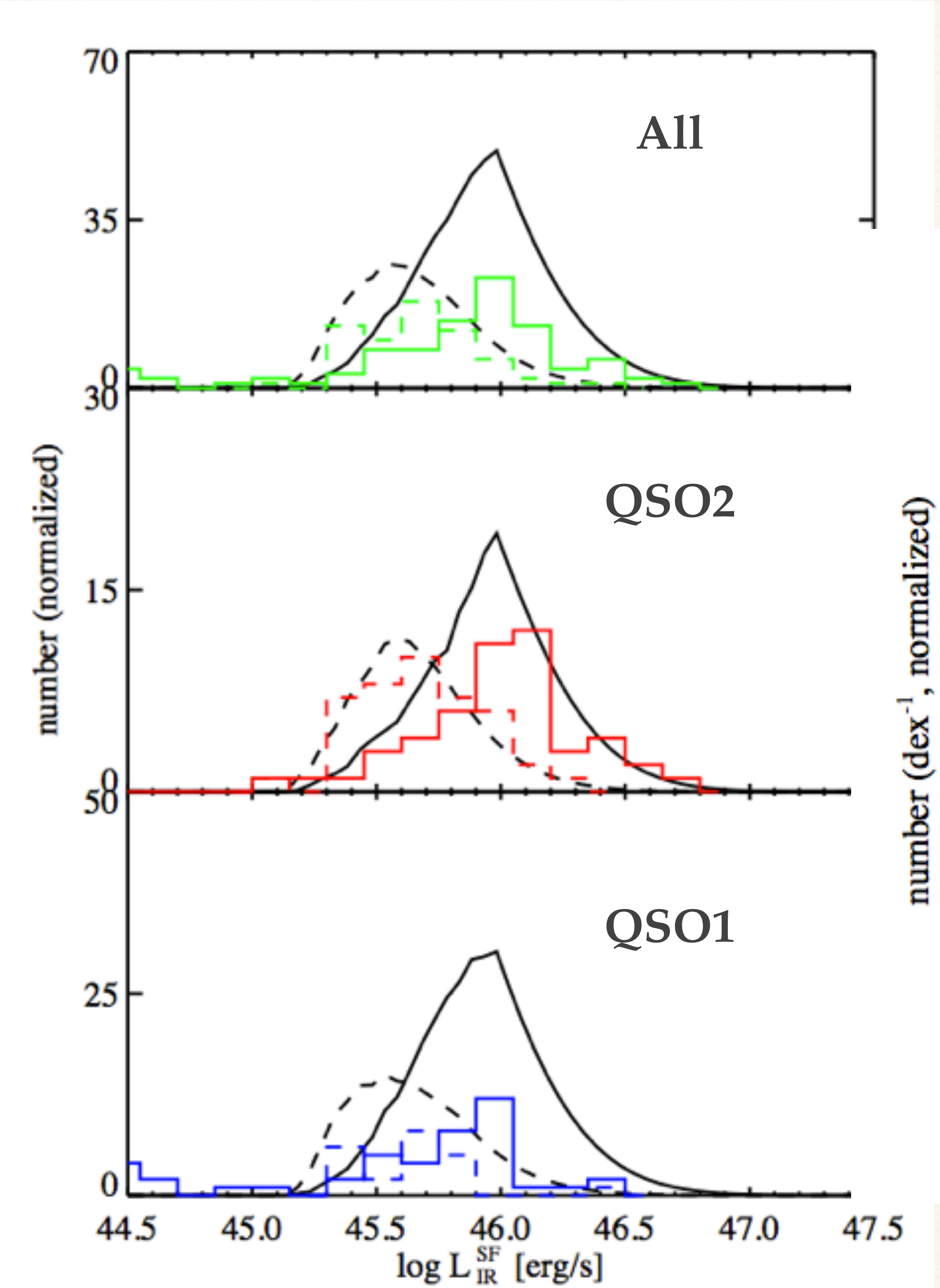
LSF(QSO2)-LSF(QSO1) >0.3 dex

Not seen in X-ray or optical samples because of sample selection bias

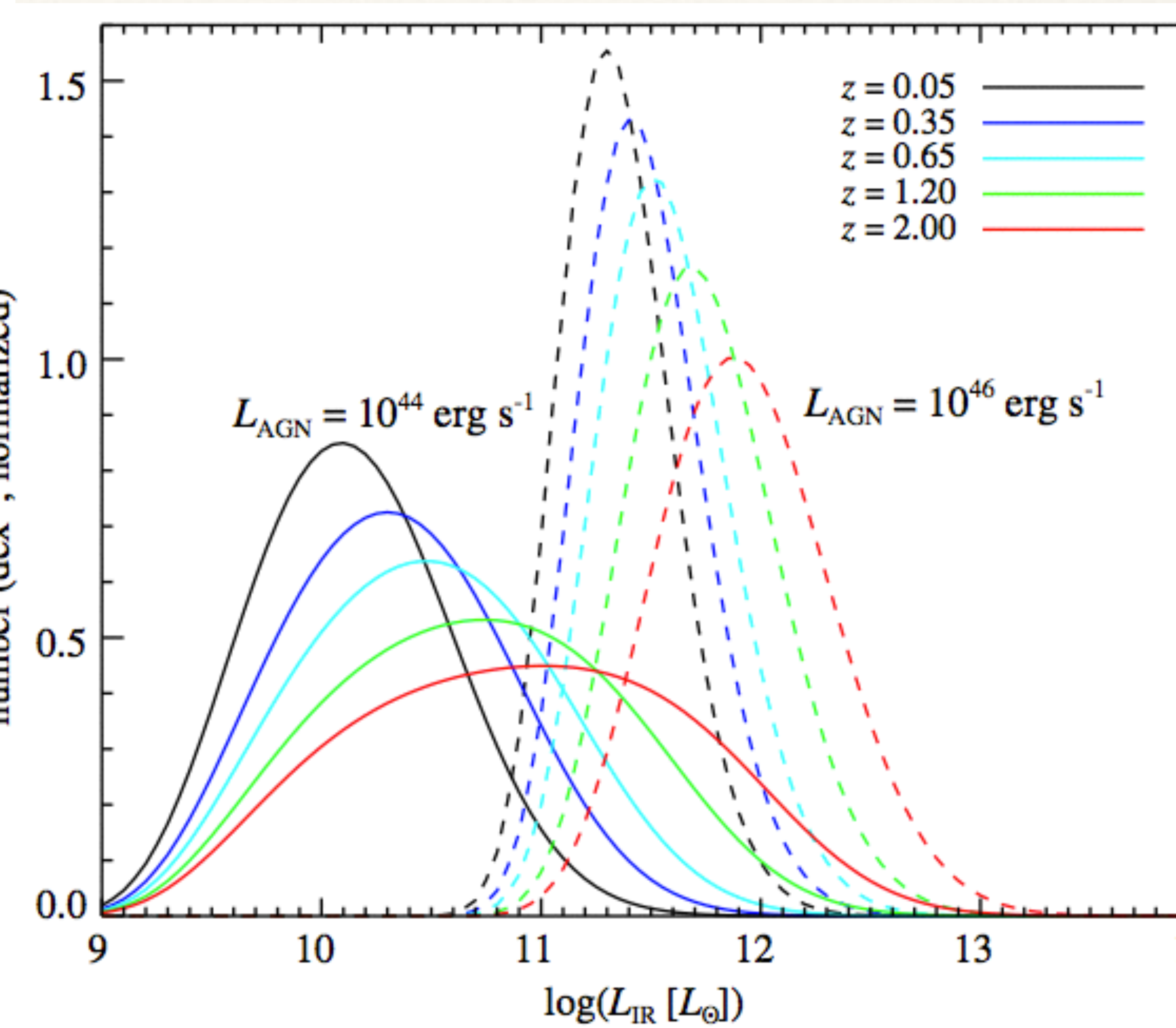
AGN accretion

Chen+ 2014 in prep

A comparison with the Hickox et al. 2014 model



Assuming a simple correlation between LSF and average LAGN



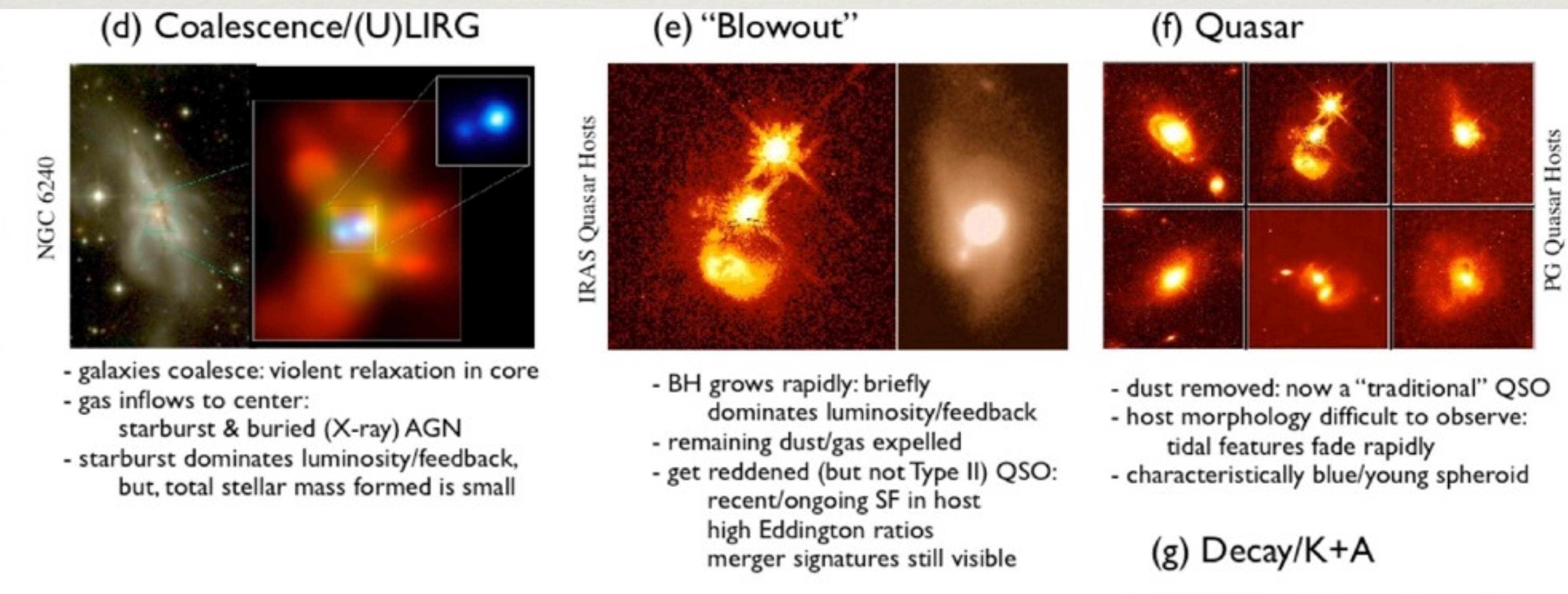
Chen+ 2014 in prep

L_{SF}-L_{AGN} correlation for QSO1s and QSO2s

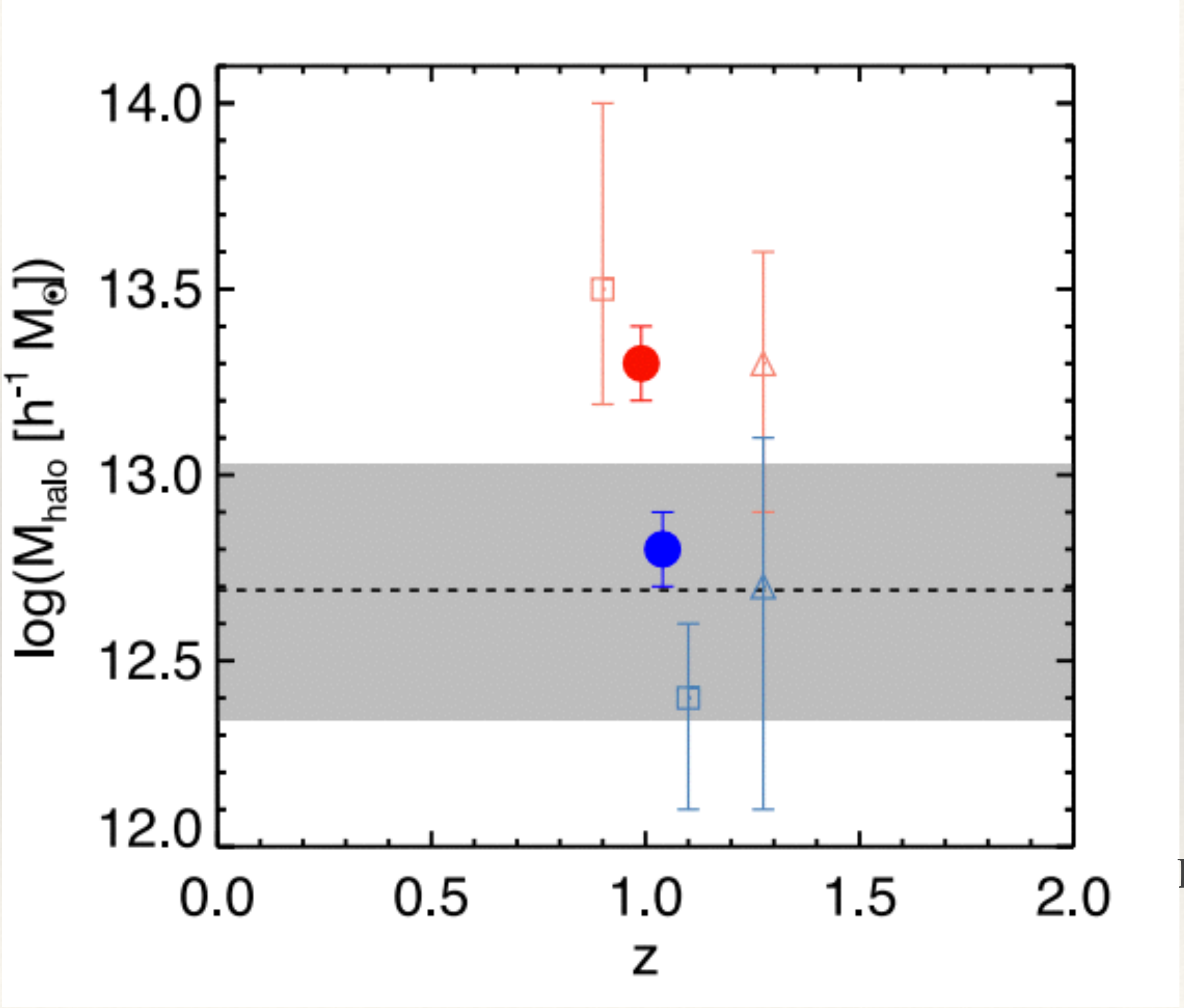
- Why are QSO2s hosted by galaxies with higher SF?
- $\log L_{SF} \propto 0.33 \log L_{AGN}$:
    - Weak correlation in comparison to some studies of local quasars and the Hickox 2014 simple model which assumes a direct connection ($\log L_{SF} \propto \log L_{AGN}$)

Why are QSO2s hosted by galaxies with higher SF?

In theoretical models, obscured phase takes place prior to the unobscured phase



QSO1s and QSO2s live in dark matter haloes of different masses

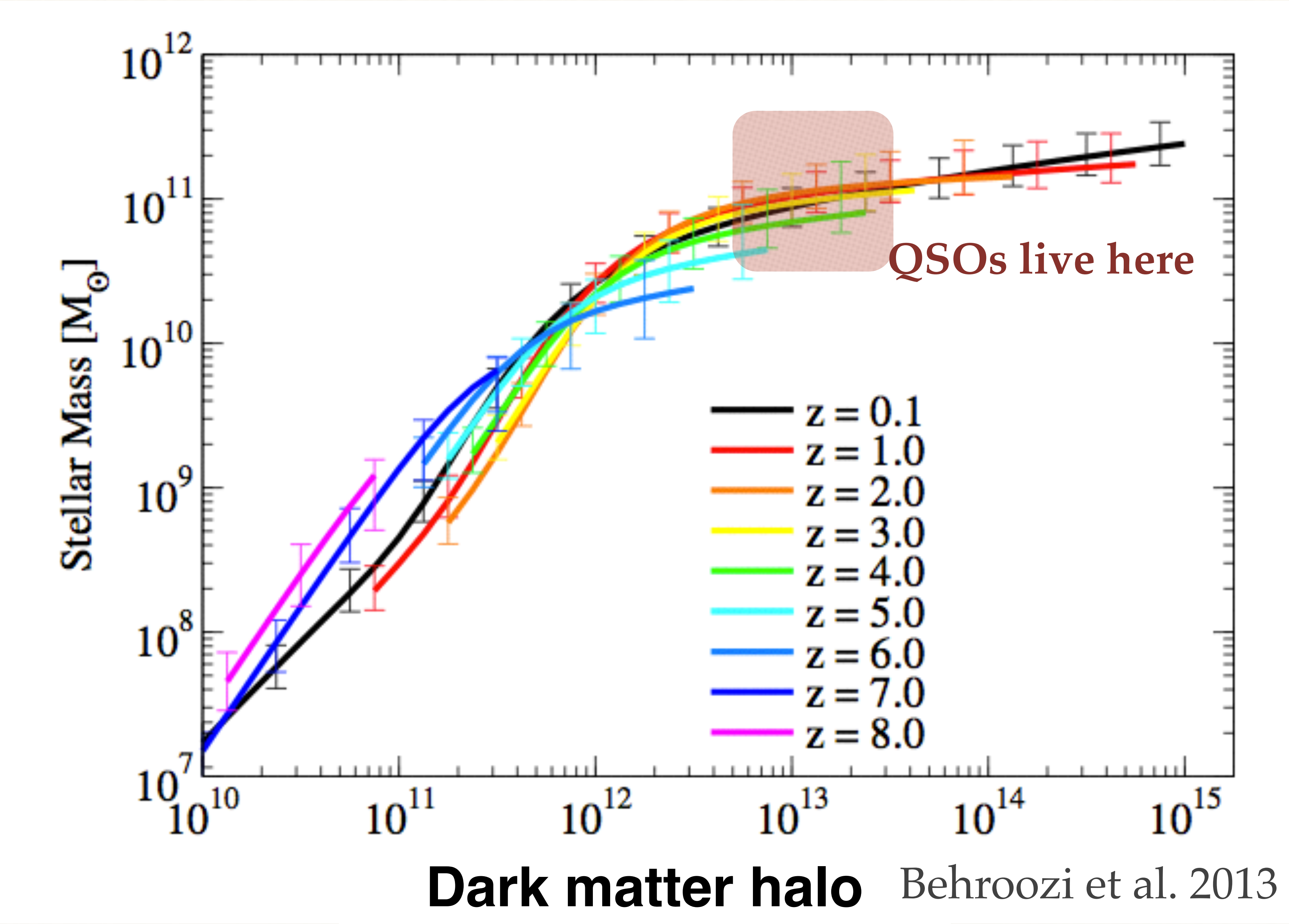


QSO2s

QSO1s

DiPompeo et al. 2014
Donoso et al. 2013
Hickox et al. 2011

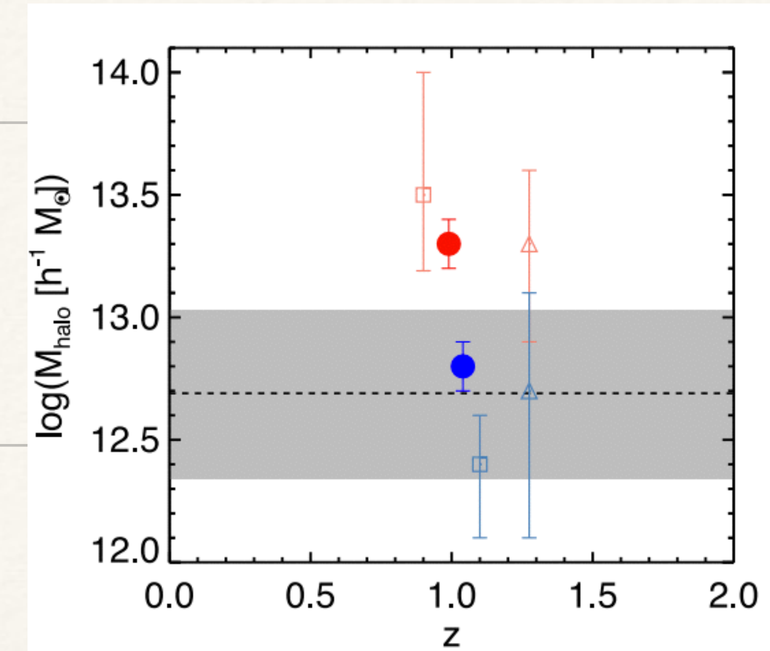
Why are QSO2s hosted by galaxies with higher SF?

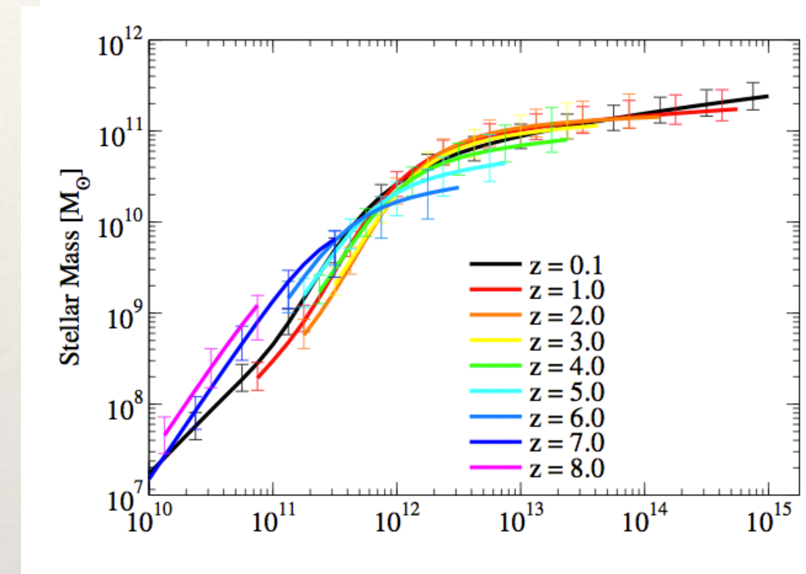


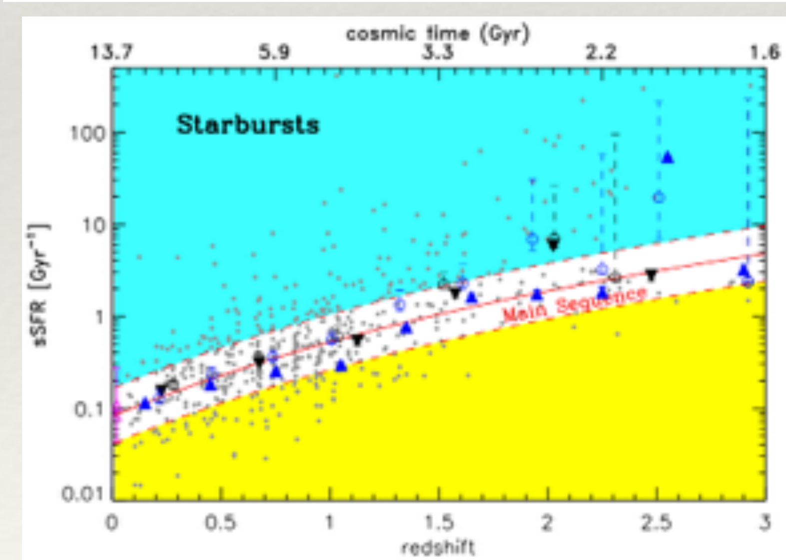
For the different DM halo masses, QSO2s are hosted by galaxies more massive than QSO1s by 0.13 dex

Are QSO2s more massive than QSO1s?

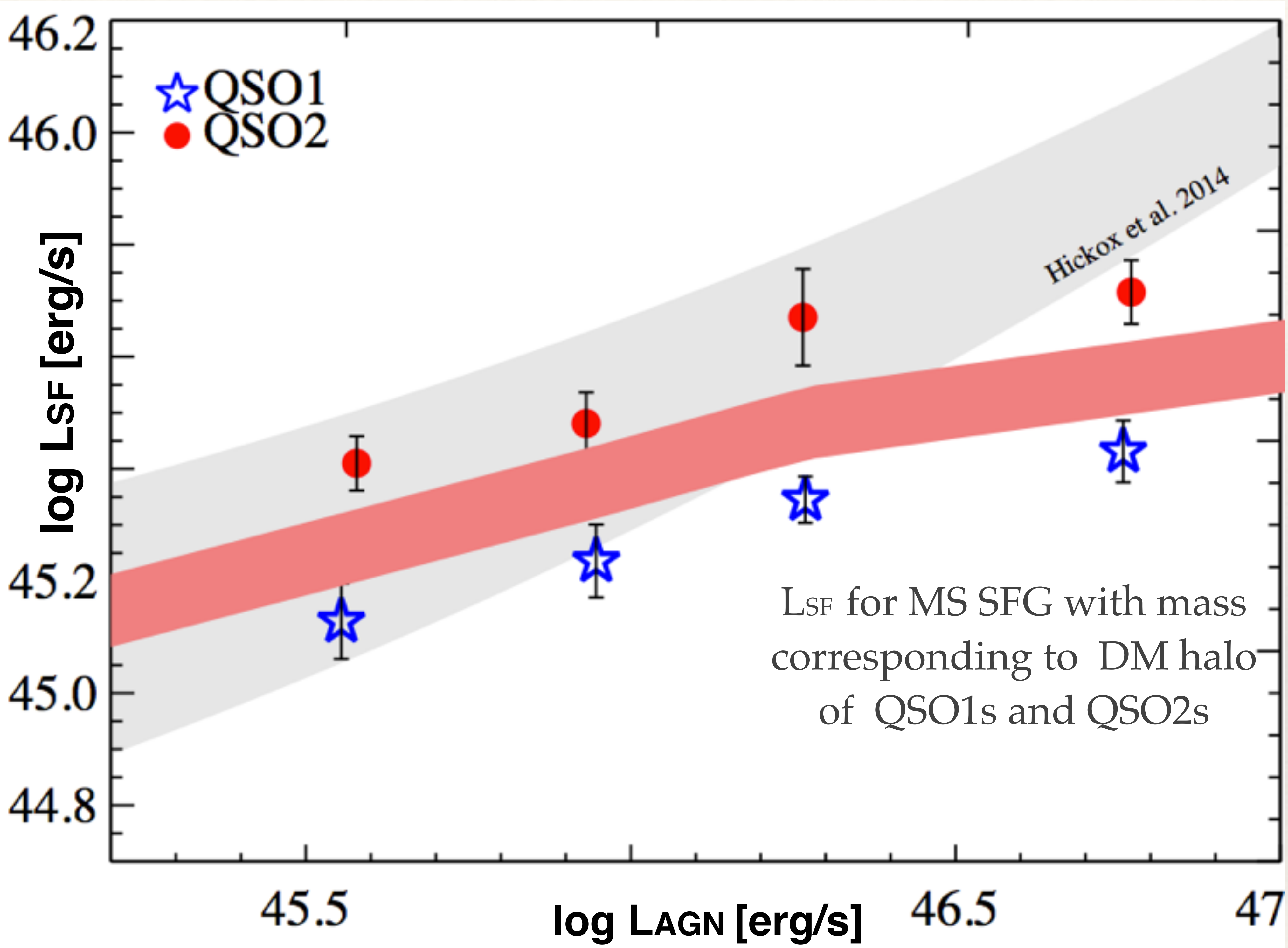
- Accurate stellar mass measurements for QSO1s are not available
- Estimate stellar mass from DM halo mass and abundance matching model (Behroozi+ 2013)
- Assuming that QSOs follow the Elbaz+ 2011 IR main sequence SF galaxy relation
- In each LAGN bin, we can estimate the LSF of normal SF galaxies living in the same DM halo with similar redshift (bootstrapping)



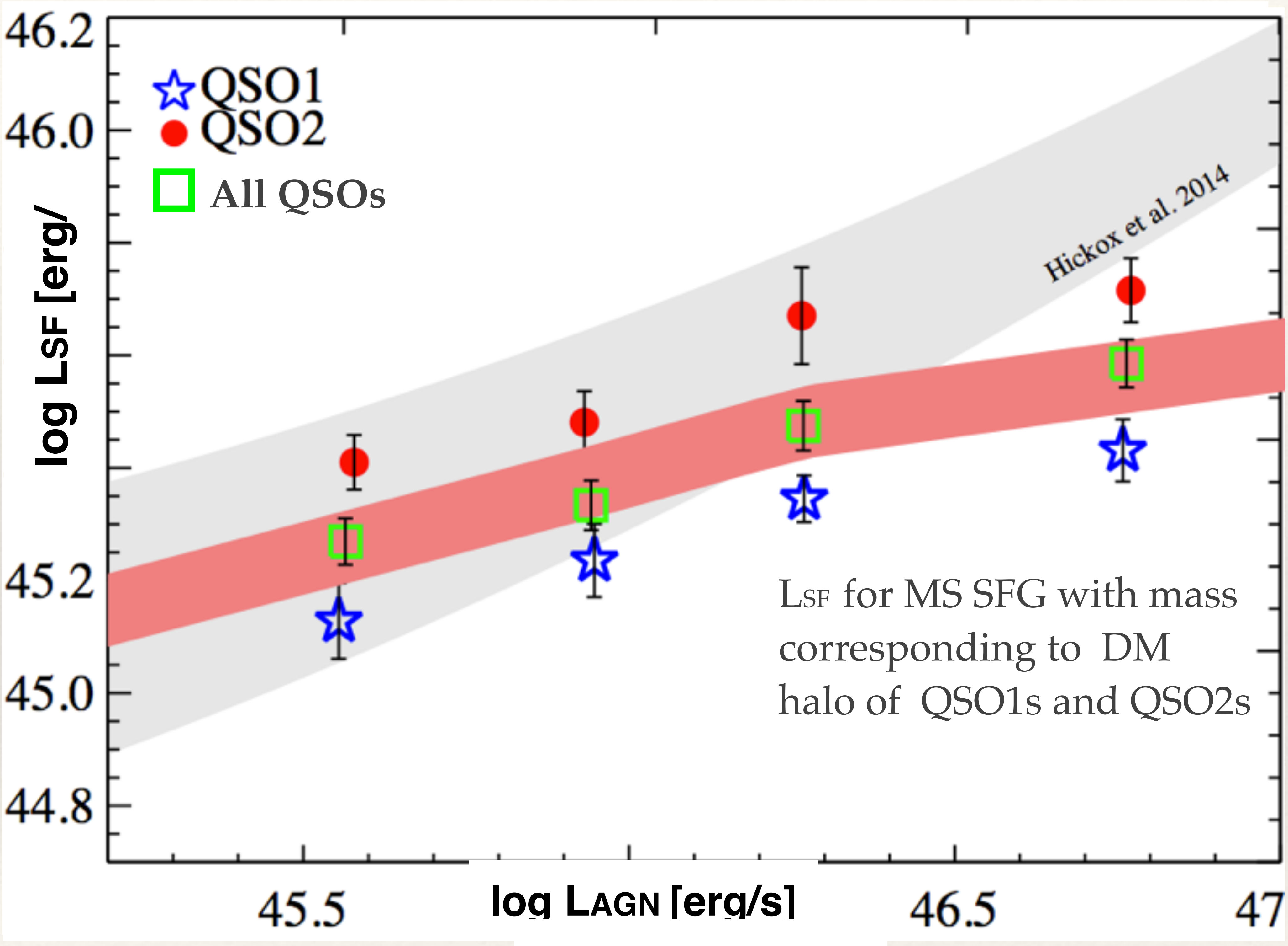




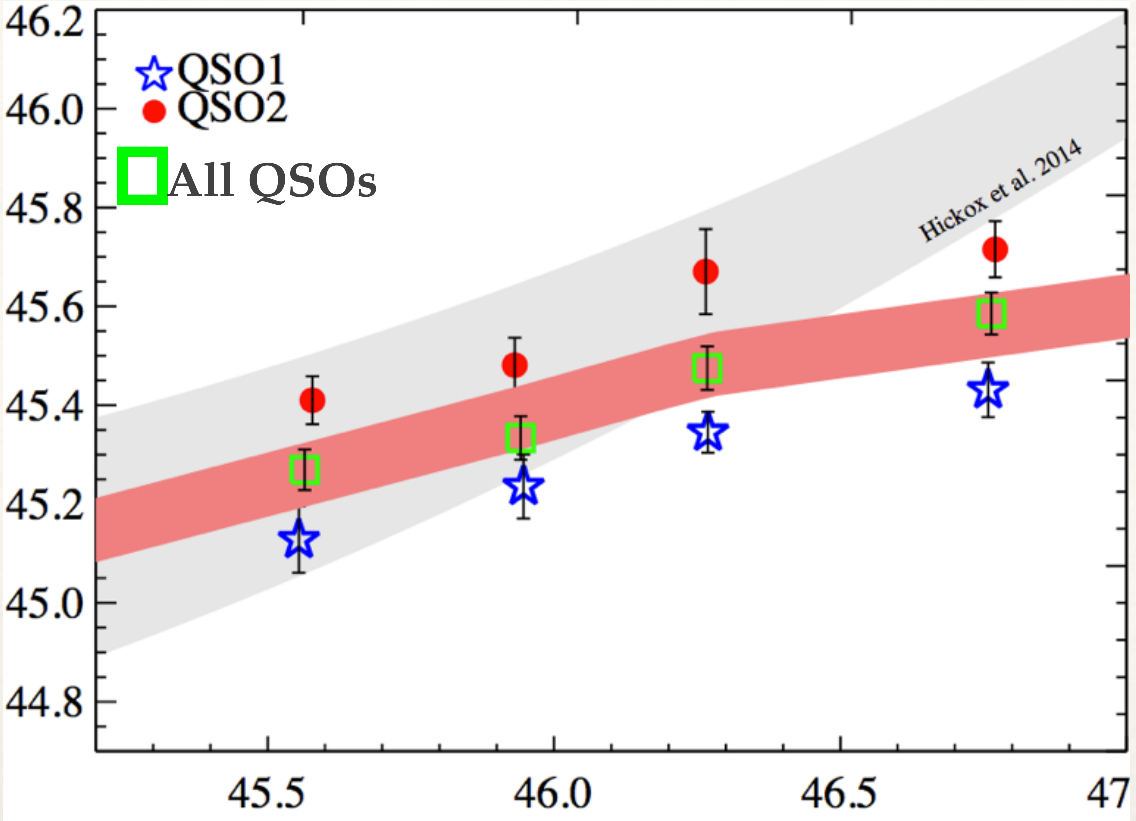
$$sSFR_{MS}\,[\mathrm{Gyr}^{-1}] = 26 \times t_{\mathrm{cosmic}}^{-2.2}$$



46.2
46.0
45.2
45.0
44.8
QSO1
QSO2
log LSF [erg/s]
Hickox et al. 2014
LSF for MS SFG with mass
corresponding to DM halo
of QSO1s and QSO2s
45.5
46.5
47
log LAGN [erg/s]



QSO1
QSO2
All QSOs
Hickox et al. 2014
LSF for MS SFG with mass corresponding to DM halo of QSO1s and QSO2s
log LSF [erg/
log LAGN [erg/s]
46.2
46.0
45.2
45.0
44.8
45.5
46.5
47



- No strong L_{SF}-L_{AGN} correlation at moderate- to high-redshift quasar sample.
- The average $\log L_{SF} \propto 0.3 \log L_{AGN}$ is consistent with the SFR evolution of main sequence SF galaxies
- DM halo mass difference between QSO1s and QSO2s is not enough to explain the observed L_{SF} difference

Conclusion

- In mid-IR quasars, part of the nuclear obscuration can be associated with the host galaxy star formation (in addition to unification model).
- At moderate redshift, mid-IR QSOs have similar L_{SF} and L_{SF} evolution similar to that of normal SF galaxies, but QSO1 and QSO2 still show differences.