



The Chandra COSMOS X-ray Survey

Vital Statistics:

1.8 Ms

1/2sq.deg

@160 ksec

1761 sources

Dec '06-June '07

Catalog 'in press'

ApJS

Martin Elvis, Francesca Civano, Aldcroft T., Fruscione A.,
Harvard Smithsonian Center for Astrophysics

Salvanto M., Vignali C., Puccetti S., Zamorani G., Brusa M., Cappelluti N.,
Fiore F., Comastri A., Salvato M., Mainieri V., Lanzuisi, G., and the
COSMOS TEAM

Another X-ray Survey?

Chandra COSMOS hits a Sweet Spot, in 3 ways

Flux



Wedding cake
Diagram

CDFs

COSMOS

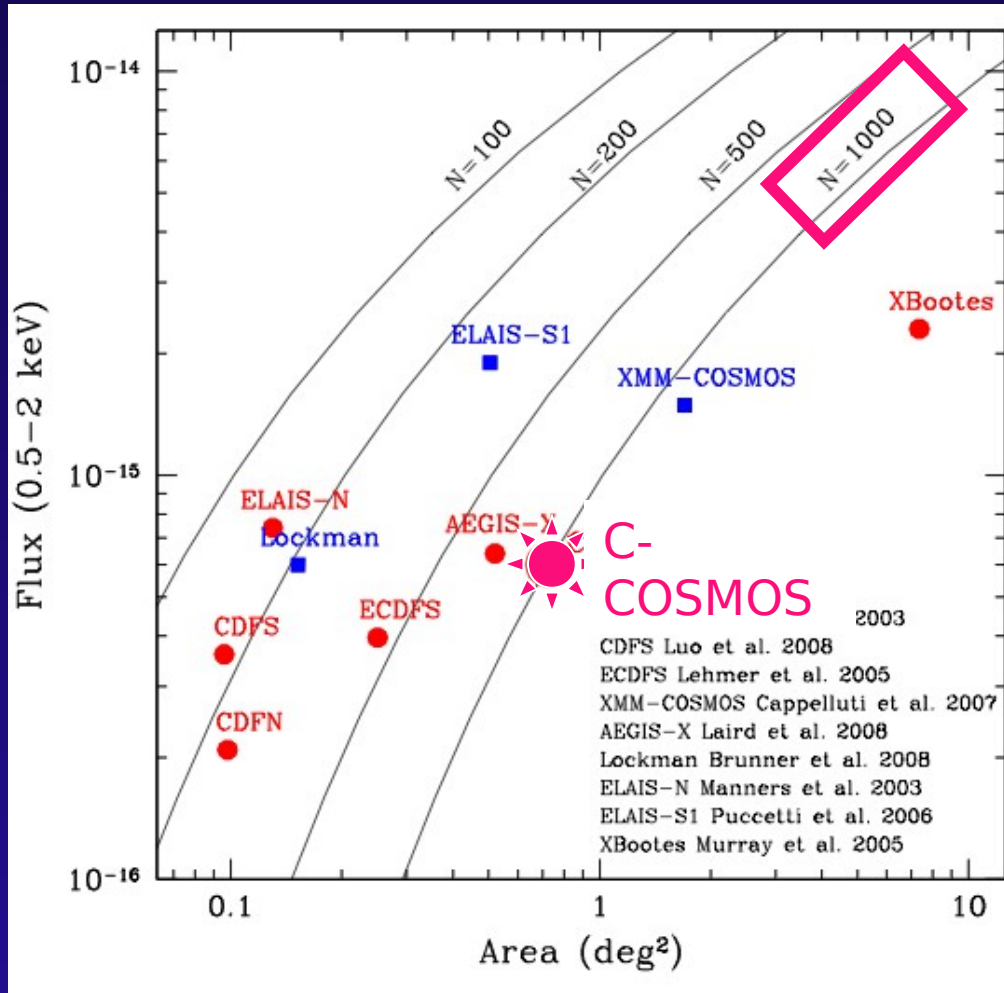
Champ

XBootes

AREA

Chandra COSMOS 1: Large Numbers

Statistics + Rare objects



1761 point sources

$f_x > 2e-16 \text{ cgs } 0.5-2 \text{ keV}$

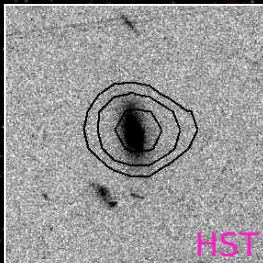
4 x fainter than XMM-COSMOS

Flux at 80% of the area

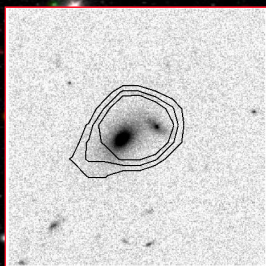
Chandra COSMOS: 2. Matched Opt/IR depth

>95% identified, 40+ photometric bands: *instant* SEDs, accurate phot-z

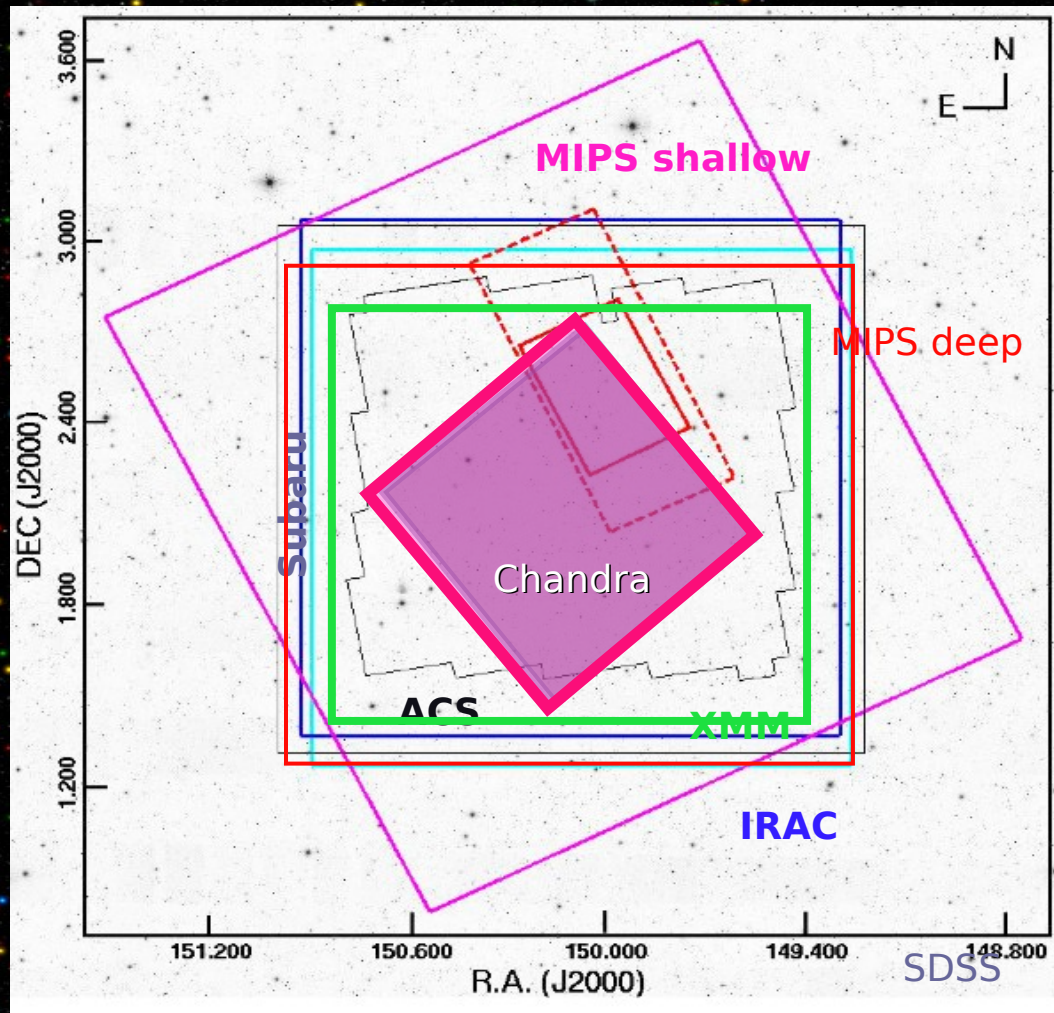
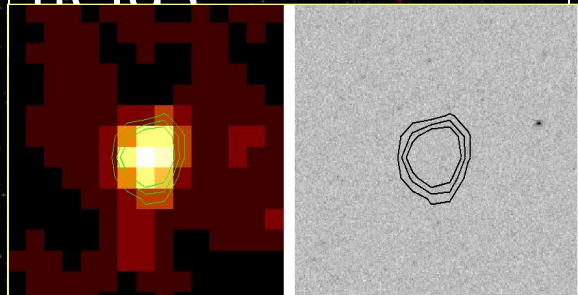
96%
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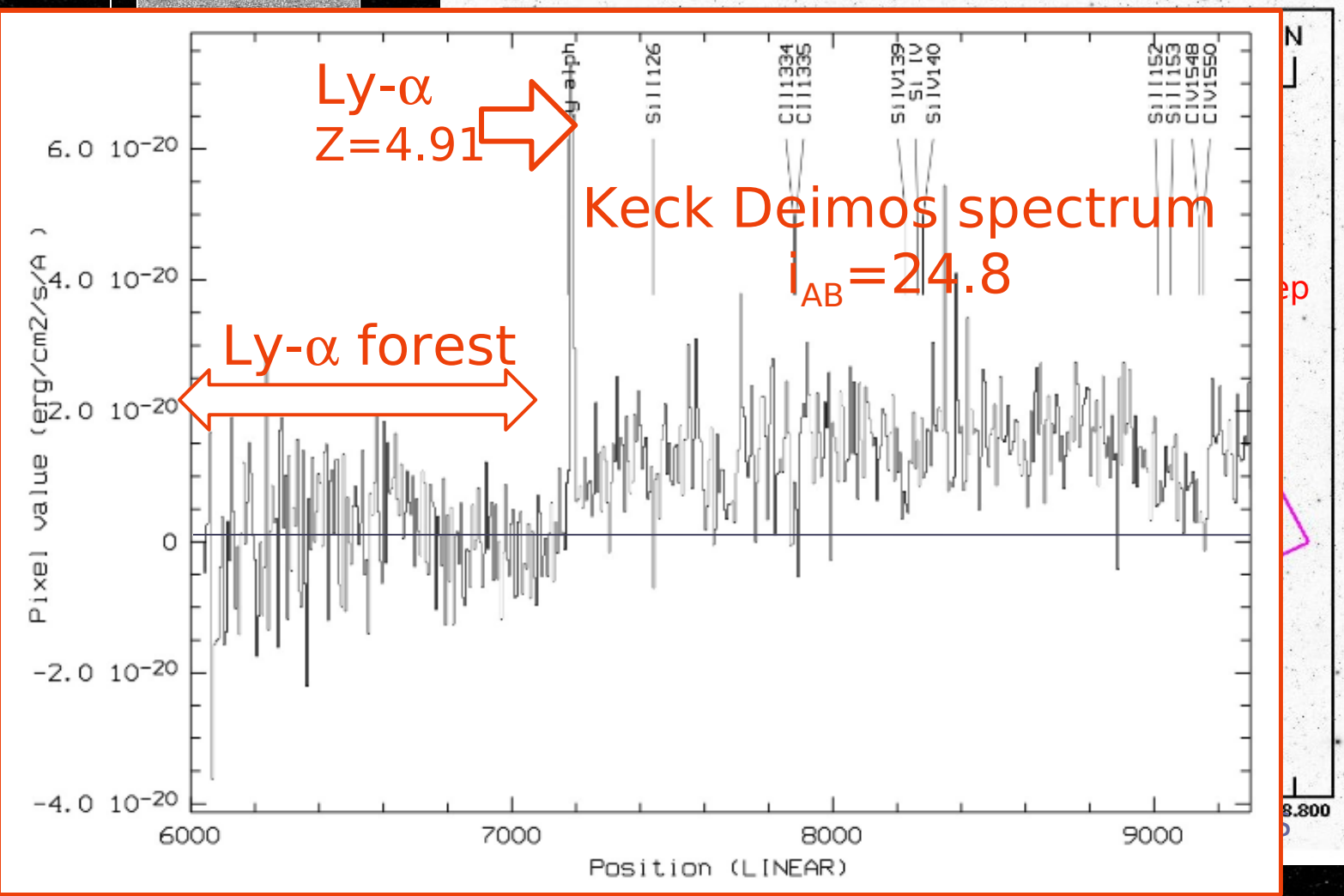
Chandra COSMOS: 2. Matched Opt/IR depth

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96%
sec
IDs

1.2
amb
us
IDs

0.3
fiel



Chandra COSMOS 3: *Not Just More*

AGN

Chandra-COSMOS reaches to a flux where galaxies outnumber type 1 AGN

XMM



Chandra



SED FITTING TEMPLATE results
Salvato et al., 2009, Civano et al. 2009

Galaxy/SMBH co-evolution via Mergers

(c) Interaction/"Merger"



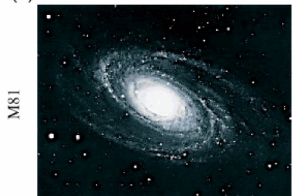
- now within one halo, galaxies interact & lose angular momentum
- SFR starts to increase
- stellar winds dominate feedback
- rarely excite QSOs (only special orbits)

(b) "Small Group"



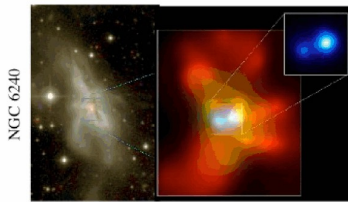
- halo accretes similar-mass companion(s)
- can occur over a wide mass range
- M_{halo} still similar to before: dynamical friction merges the subhalos efficiently

(a) Isolated Disk



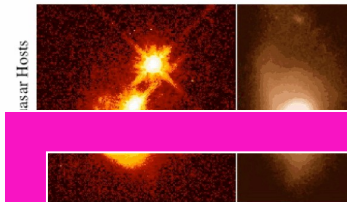
- halo & disk grow, most stars formed
- secular growth builds bars & pseudobulges
- "Seyfert" fueling (AGN with $M_{\text{BH}} > 23$)
- cannot redden to the red sequence

(d) Coalescence/(U)LIRG



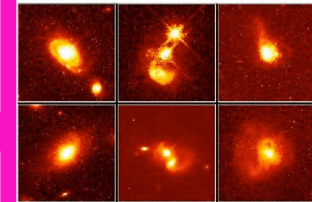
- galaxies coalesce: violent relaxation in core
- gas inflows to center: starburst & buried (X-ray) AGN
- starburst dominates luminosity/feedback, but, total stellar mass formed is small

(e) "Blowout"



- BH grows rapidly: briefly dominates luminosity/feedback
- remaining dust/gas expelled
- get reddened (but not Type II) QSO: recent/ongoing SF in host
- high Eddington ratios
- merger signatures still visible

(f) Quasar



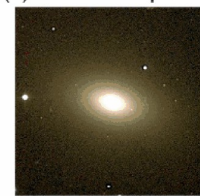
- dust removed: now a "traditional" QSO
- host morphology difficult to observe: tidal features fade rapidly
- characteristically blue/young spheroid

(g) Decay/PA



- QSO luminosity fades rapidly
- tidal features visible only with very deep observations
- remnant reddens rapidly (E+A/K+A)
- "hot halo" from feedback
- sets up quasi-static cooling

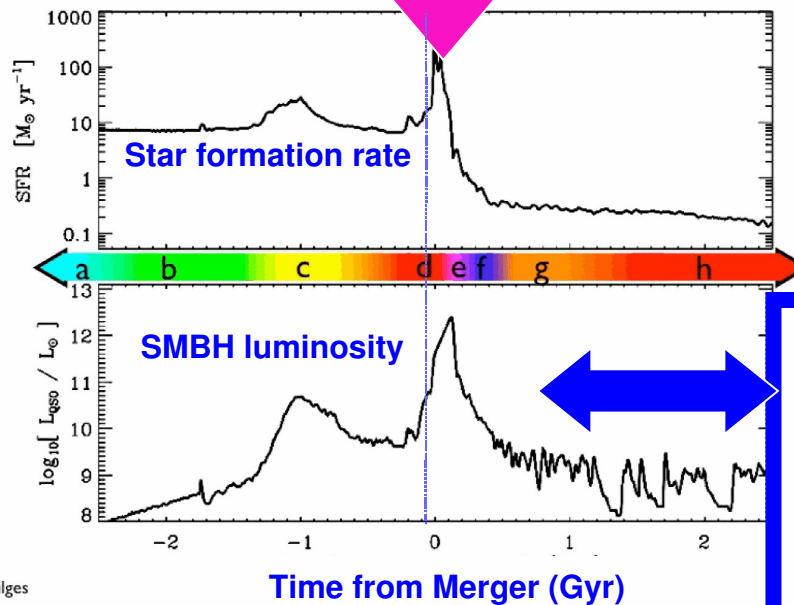
(h) "Dead" Elliptical



- star formation terminated
- large BH/spheroid - efficient feedback
- halo grows to "large group" scales: mergers become inefficient
- growth by "dry" mergers

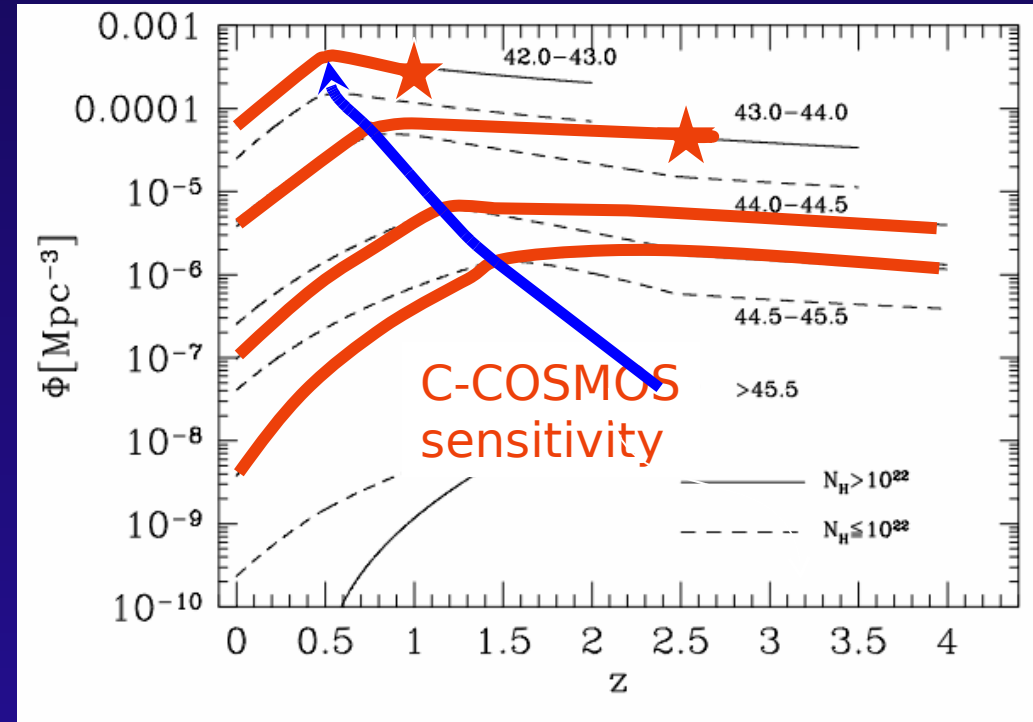
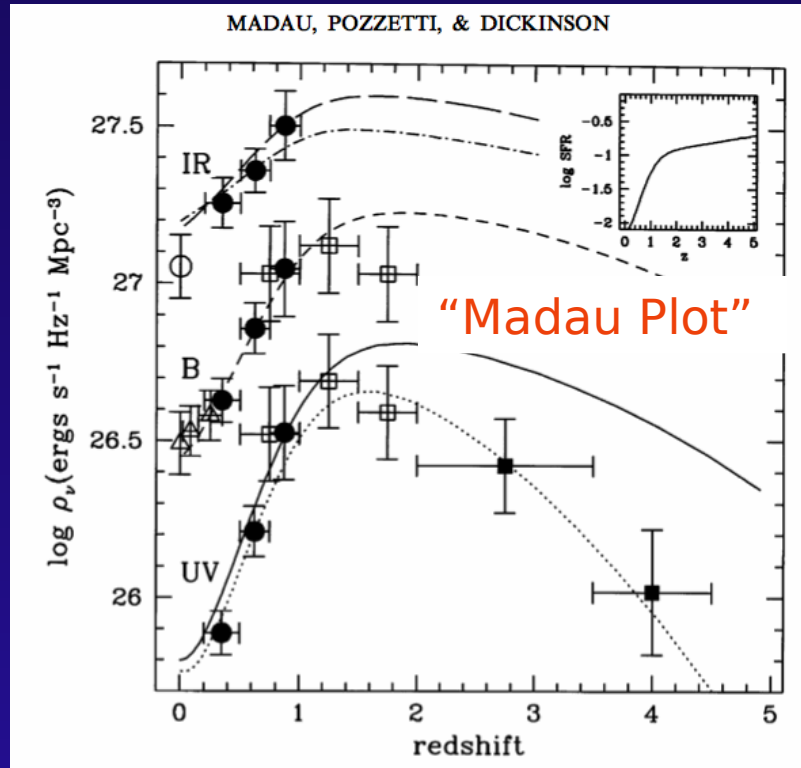
QUASAR phase: BH fed rapidly by merger, starburst
High L/L_{edd}

'RADIO'/Seyfert phase: BH fed slowly by stellar mass loss; Low L/L_{edd}



Downsizing in Star Formation and SMBH

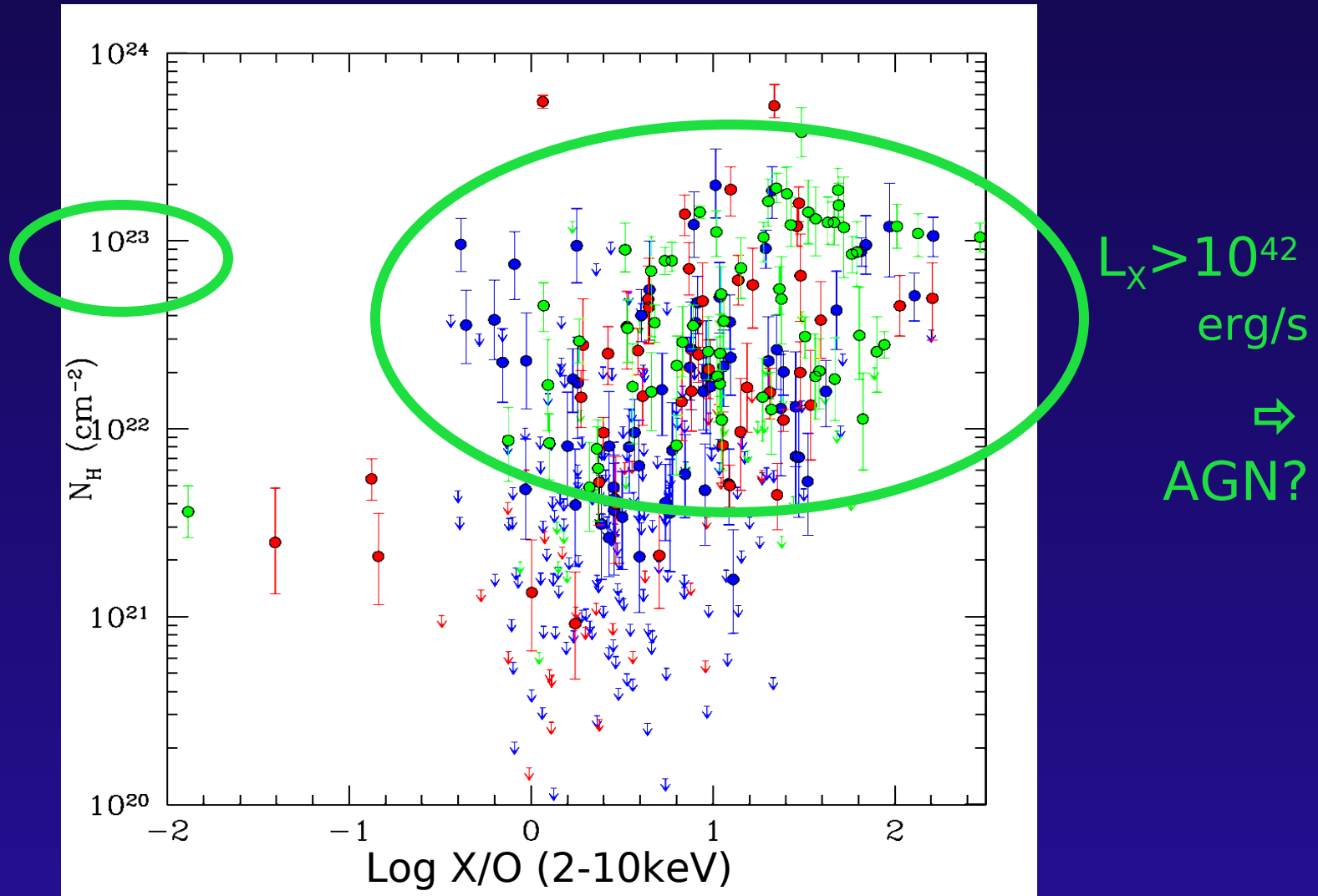
- Star-formation and SMBH peak at $z=1-2$
- **Co-evolution?** onset of AGN feedback, assembly of spheroids, hosts to quasars and relic SMBH
- Central to design of COSMOS, C-COSMOS



- DOGs” Massive, young, strongly star-forming at $z=1-2$

DOGs: AGNs or Starbursts?

Bright Chandra-COSMOS DOGs at $z=1-2$ are heavily obscured

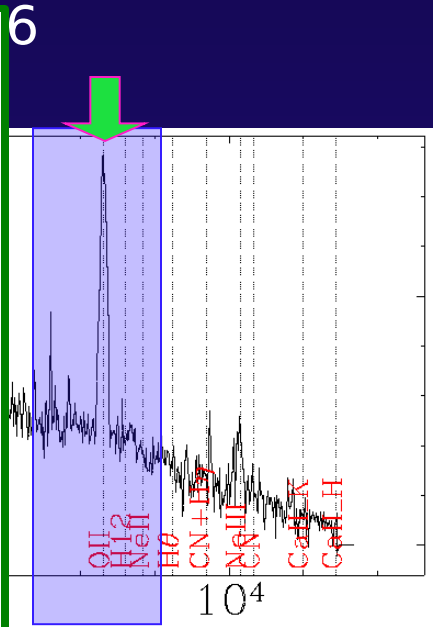
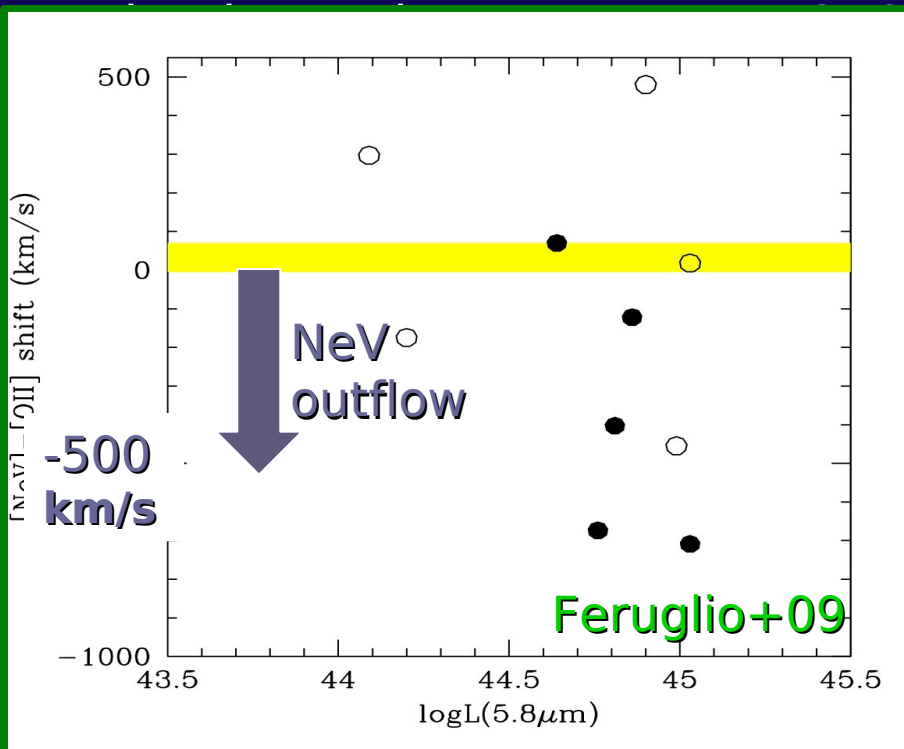
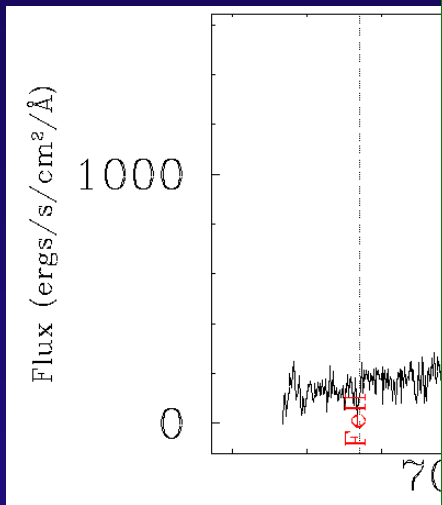


Lanzuisi et al., 2009, in preparation

Both!

Coeval growth of SMBH & Host at z~1-2

AG Starburst



3.5 hours of integrations

z=1.592 $L_x = 5 \times 10^{44} \text{ erg s}^{-1}$

Update: ~80 new redshifts from 150 C-COSMOS slits,

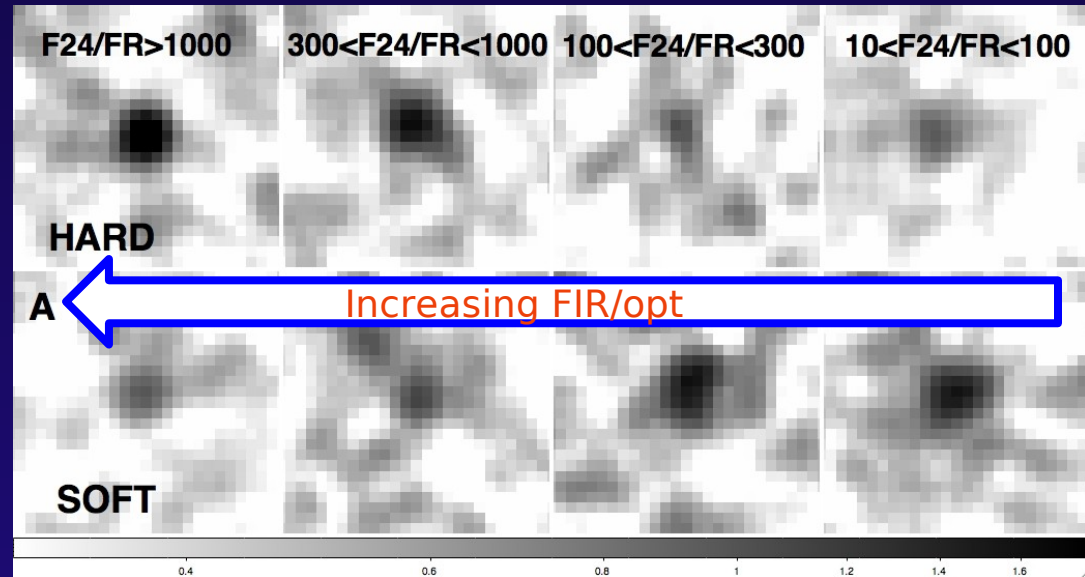
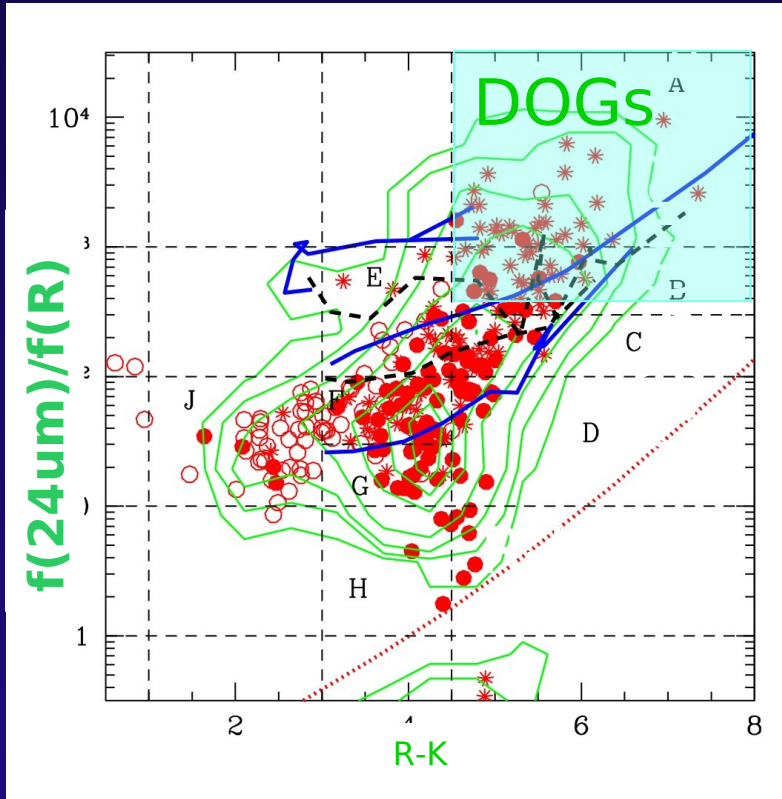
$I_{AB} \sim 23.5$

More nights in February 2010

Salvato et al., 2009, in preparation

COSMOS MIR DOGs

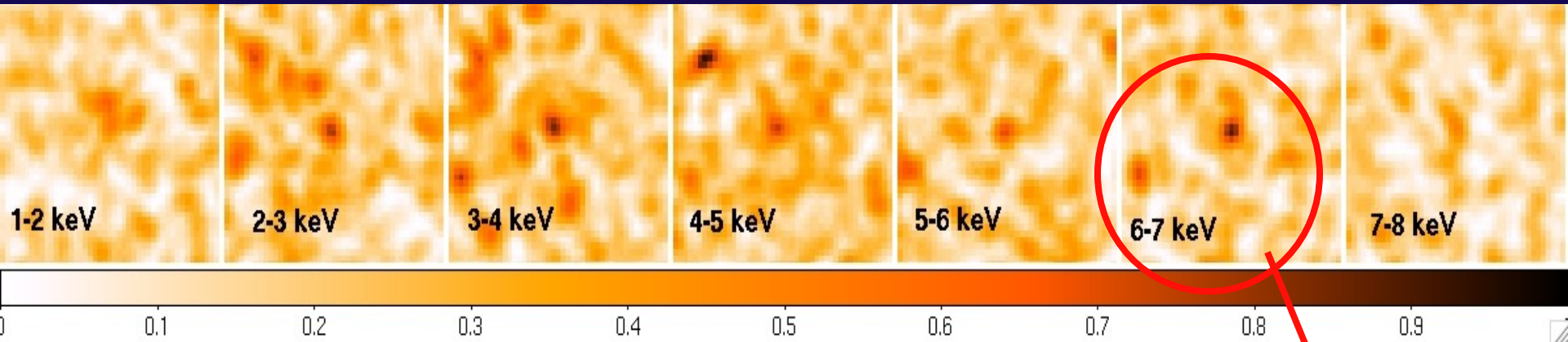
Fainter DOGs also obscured



**Stack of Chandra images
of MIR sources not
directly detected in C-
COSMOS**

Chandra DOGs stacked in *Rest Frame*

Strong Fe-K Emission line: Compton Thick AGNs?



MIR Bright DOGs

99 sources with:

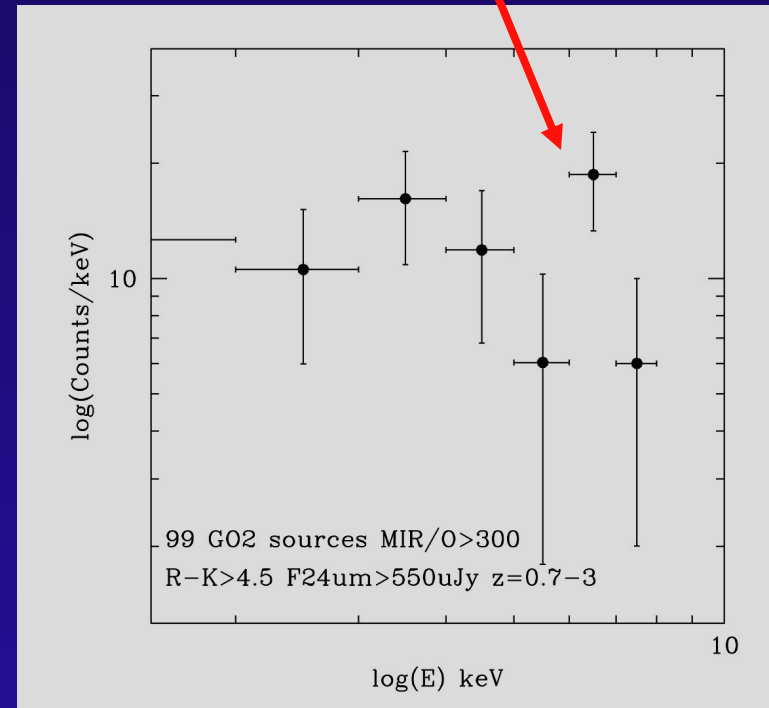
$F_{24\mu\text{m}} > 550 \mu\text{Jy}$

$\text{MIR}/\text{O} > 300$

$R-K > 4.5$

All with redshifts

$0.7 < z < 3$



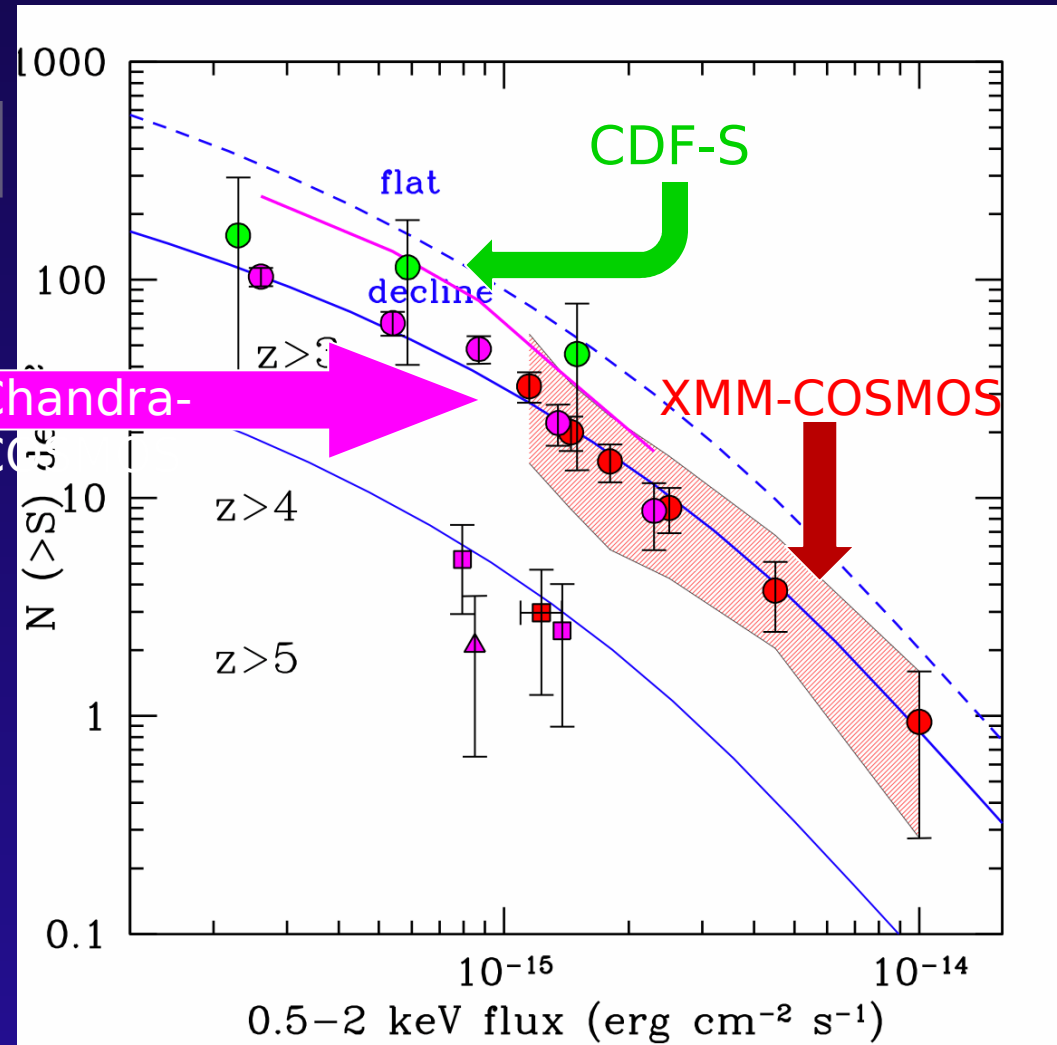
Fiore et al., 2009, in preparation

Z>3 Quasars

Good Statistics at last

54 z>3 quasars (phot-z)

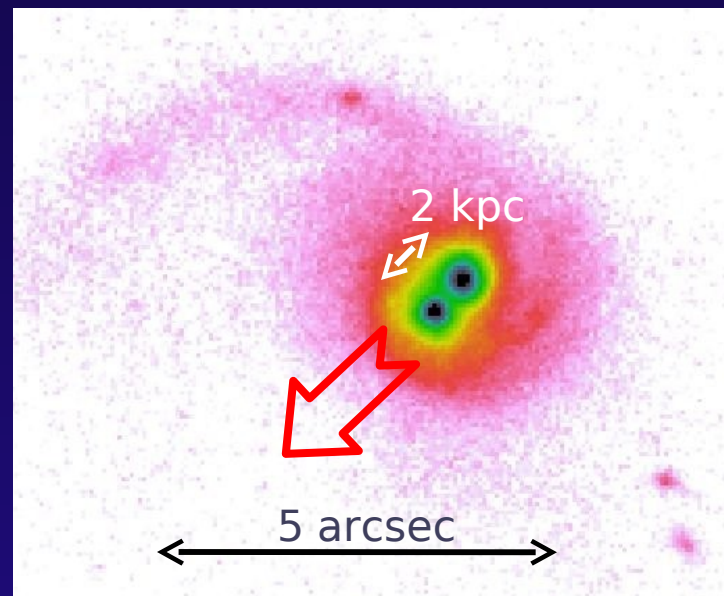
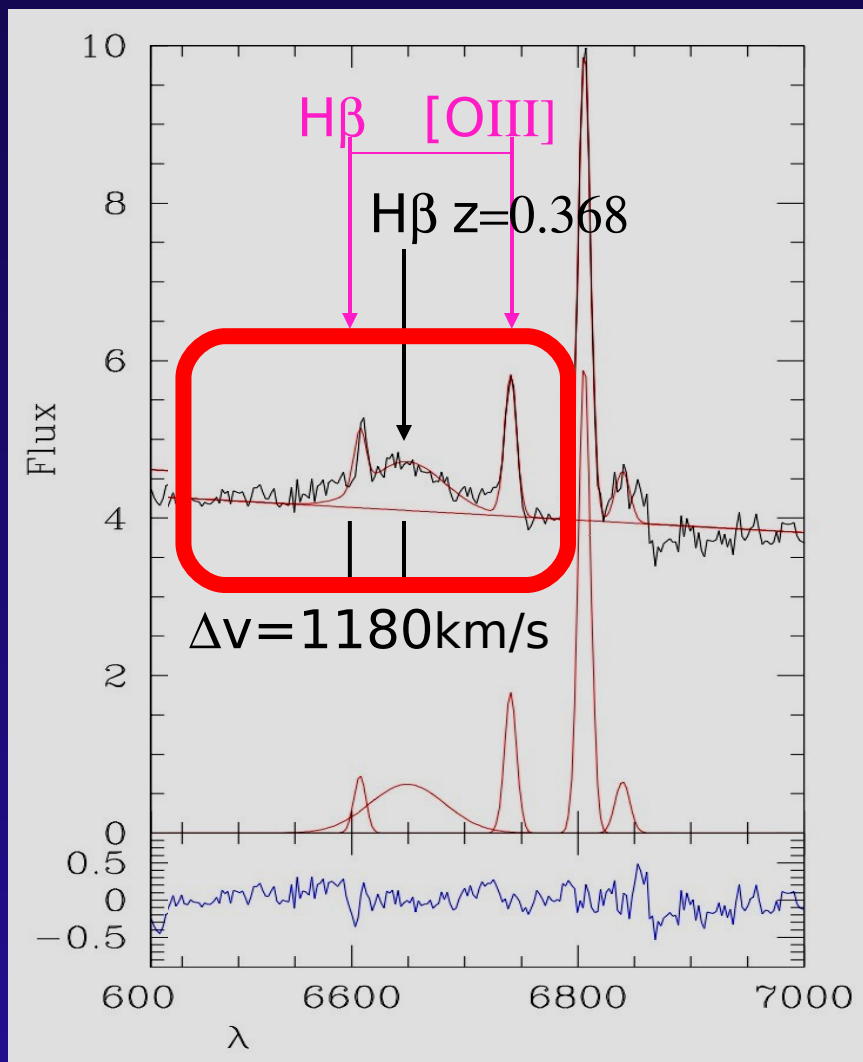
logN-logS has small errors
⇒ Discriminates models
⇒ Cut-off at z>2.7



CDF-S: Fiore et al
XMM-COSMOS: Brusa et al. 2009
Chandra-COSMOS: Civano et al. 2009

Rare Objects: 1 Double Nucleus/1761 sources

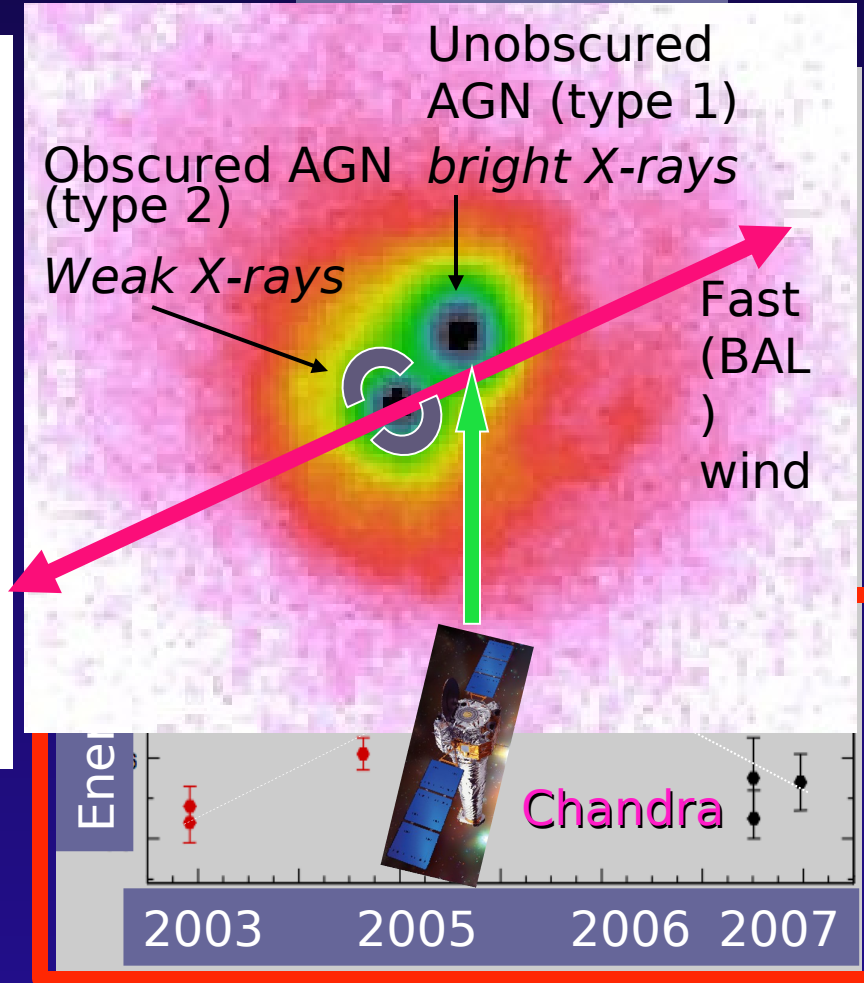
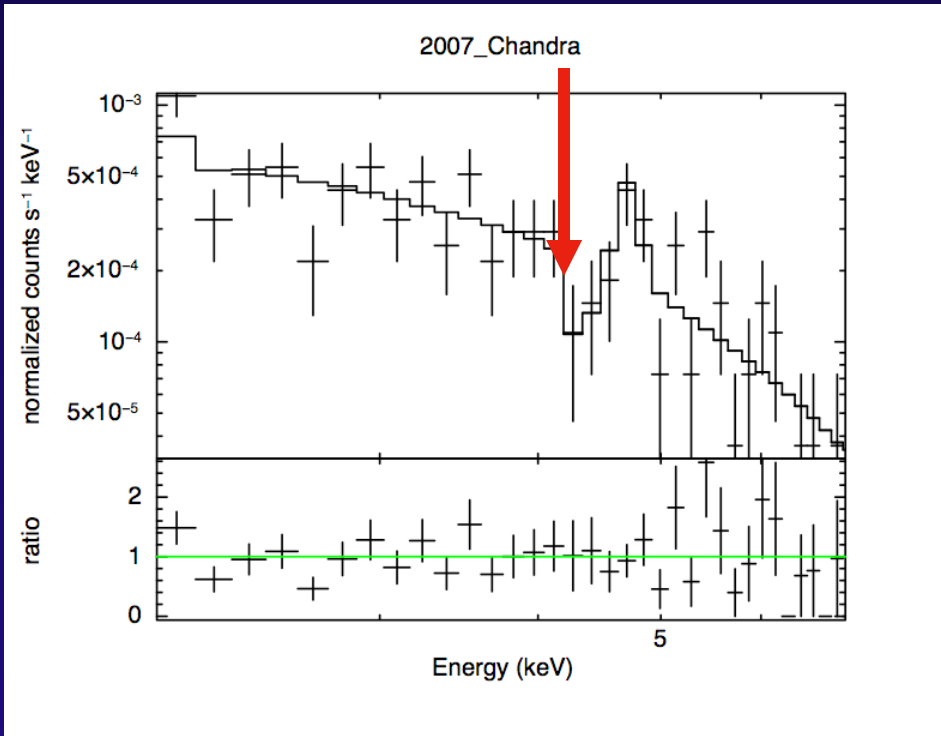
Gravitational Wave Recoil ?



Just-merged SMBH get kick from
Gravitational Waves
Ejected at up to 4000 km/s
Accretion disk, BLR tightly bound
-> move with SMBH

Also Redshifted, Variable Energy Fe-K

Absorption Backlit BAL Wind?



$\forall \Delta E = 500 \text{ eV} \Rightarrow 10^4$
km/s/yr

0.02-0.07c FeI

0.09-0.14c FeXXVI

- BAL Wind in an Obscured AGN

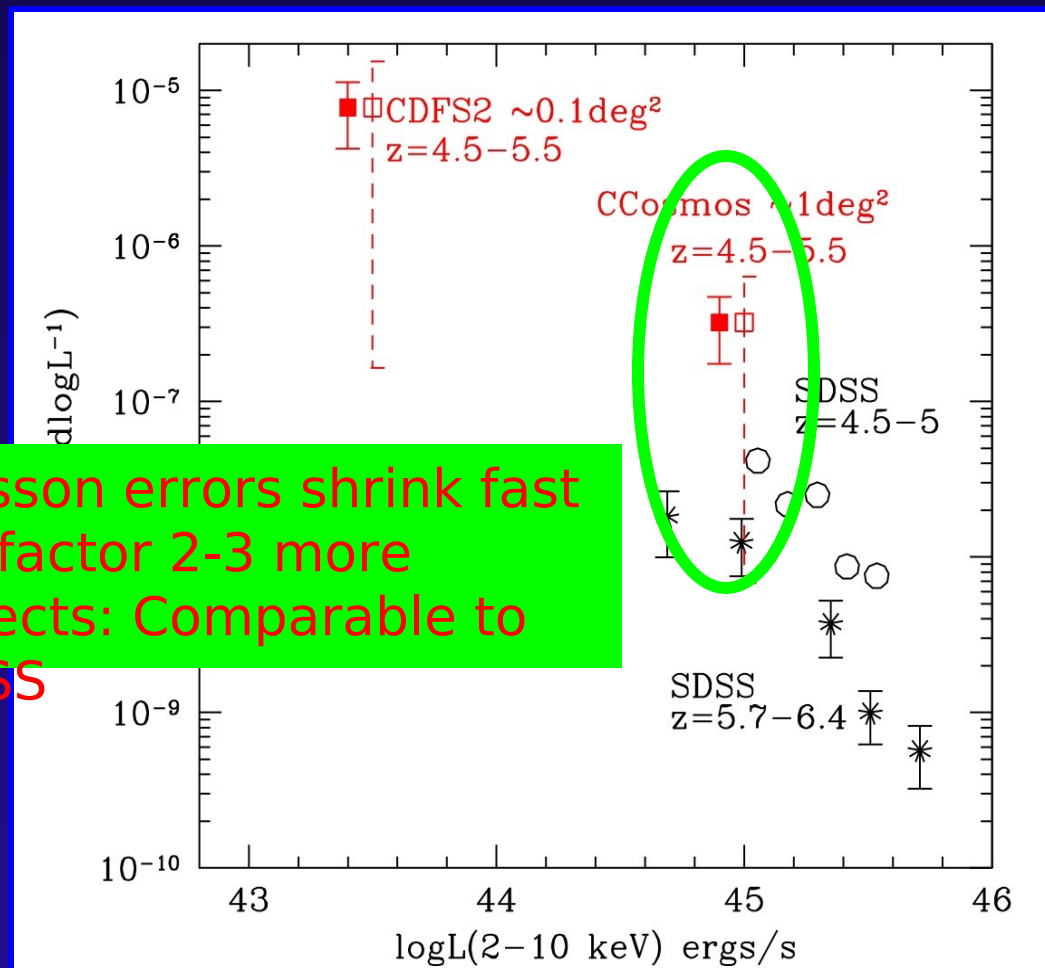
Next : "The Complete Chandra COSMOS Survey"

CC-COSMOS: rare objects become common

2.45 Ms
1.7 sq.deg
@ 160 ksec
3600 pt. Sources

- AGN-Galaxy CCF to $z=2$
- AGN lensing by z , type
- Group lensing by type
- LIRG, AGN clustering @ $z>1$
- AGN L/L_{Edd} in SB, passive hosts
- $z>7$ quasars (UltraVista)

Poisson errors shrink fast
for factor 2-3 more
objects: Comparable to
SDSS



Also: SEDS, Herschel, AzTEC, Ultra-VISTA, Keck...



The Chandra COSMOS Survey: A high resolution X-ray legacy

C-COSMOS Vital Statistics:

1.8 Ms

1/2sq.deg

@160 ksec

1761 sources

Dec '06-June '07

Catalog :2009 ApJS,184, 158

***Data products available at
IRSA***

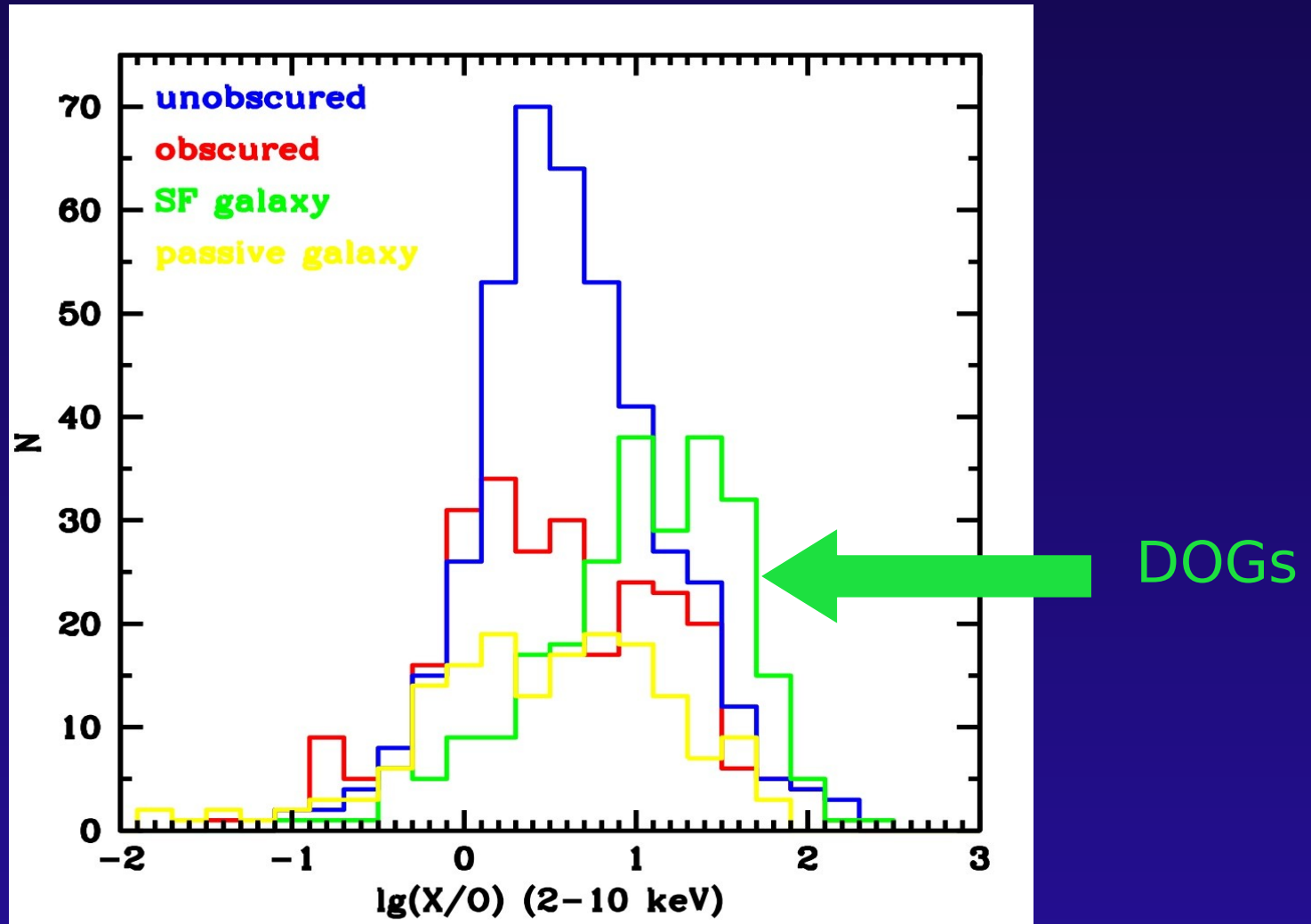
Martin Elvis, Francesca Civano, Aldcroft T., Fruscione A.,
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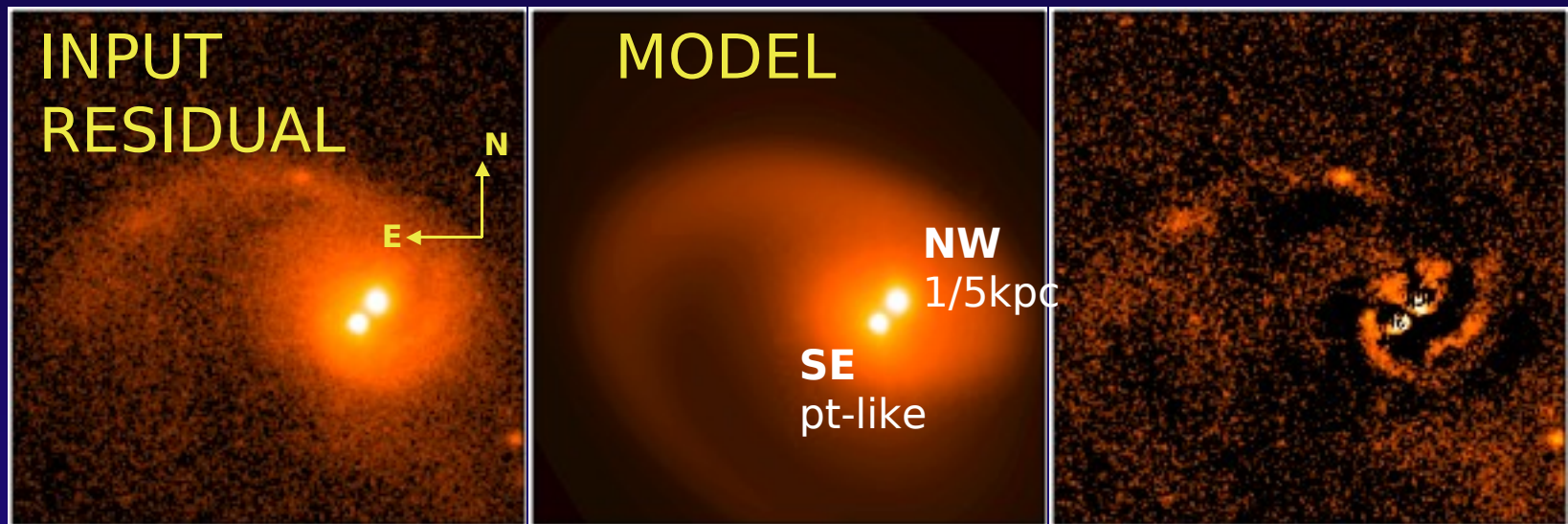
COSMOS TEAM

X-ray DOGs

Chandra-COSMOS Galaxies have high X-ray/Optical ratios



Double Nucleus: 2kpc separation



HST ACS F814W image

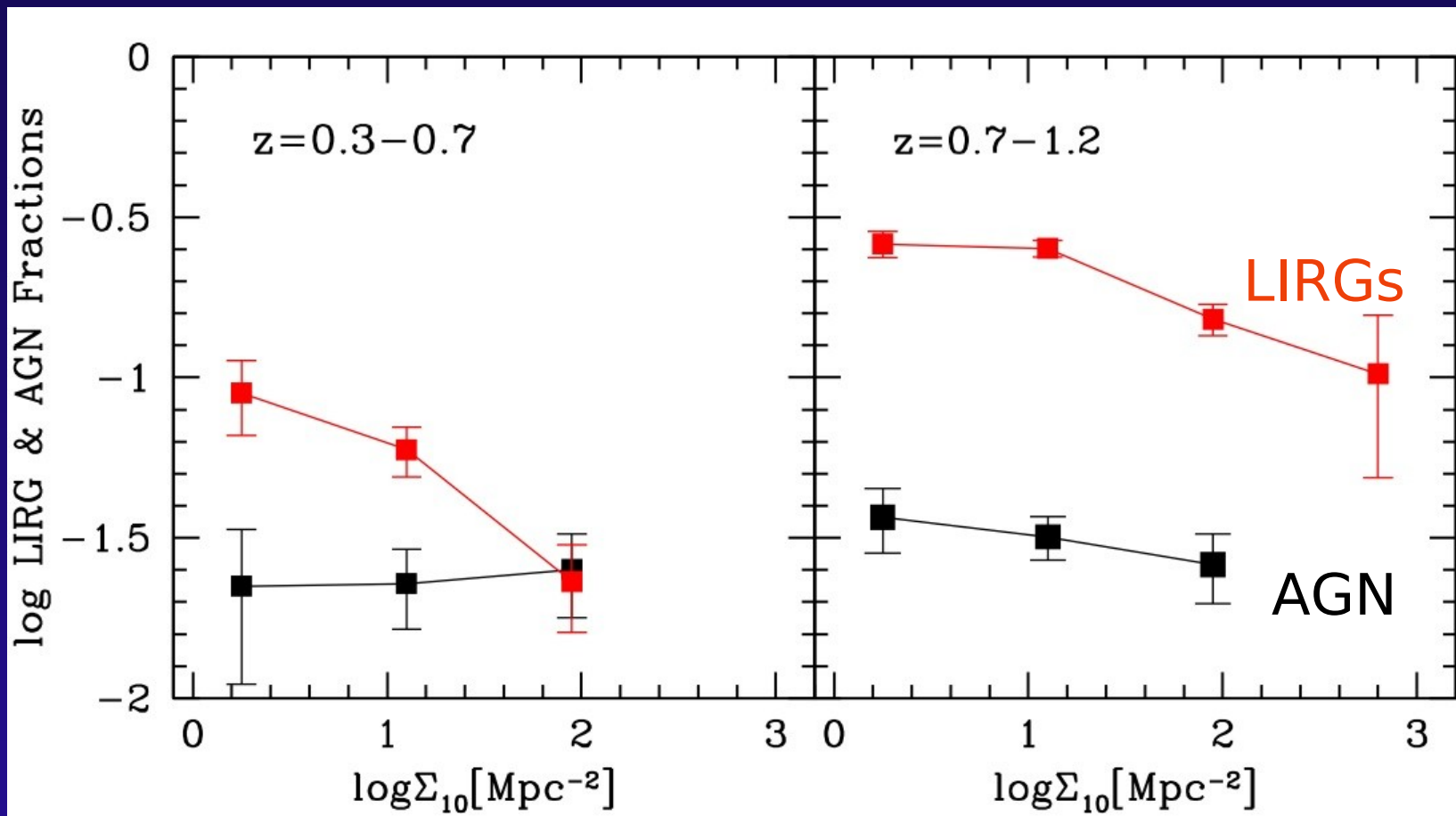
GALFIT 4 component MODEL:

- 1 PSF --> SE nucleus (20.51 mag) --> Type 1AGN
- + 1 compact --> NW nucleus (19.67 mag) --> Type 2 AGN
- + 1 extended --> galaxy (~15 kpc, 18.6 mag)
- + 1 asymmetric --> tail and overall light

statistical
CS

AGN vs. Starburst Clustering

At $z \sim 1$ Starbursts & AGN do not yet avoid high density regions

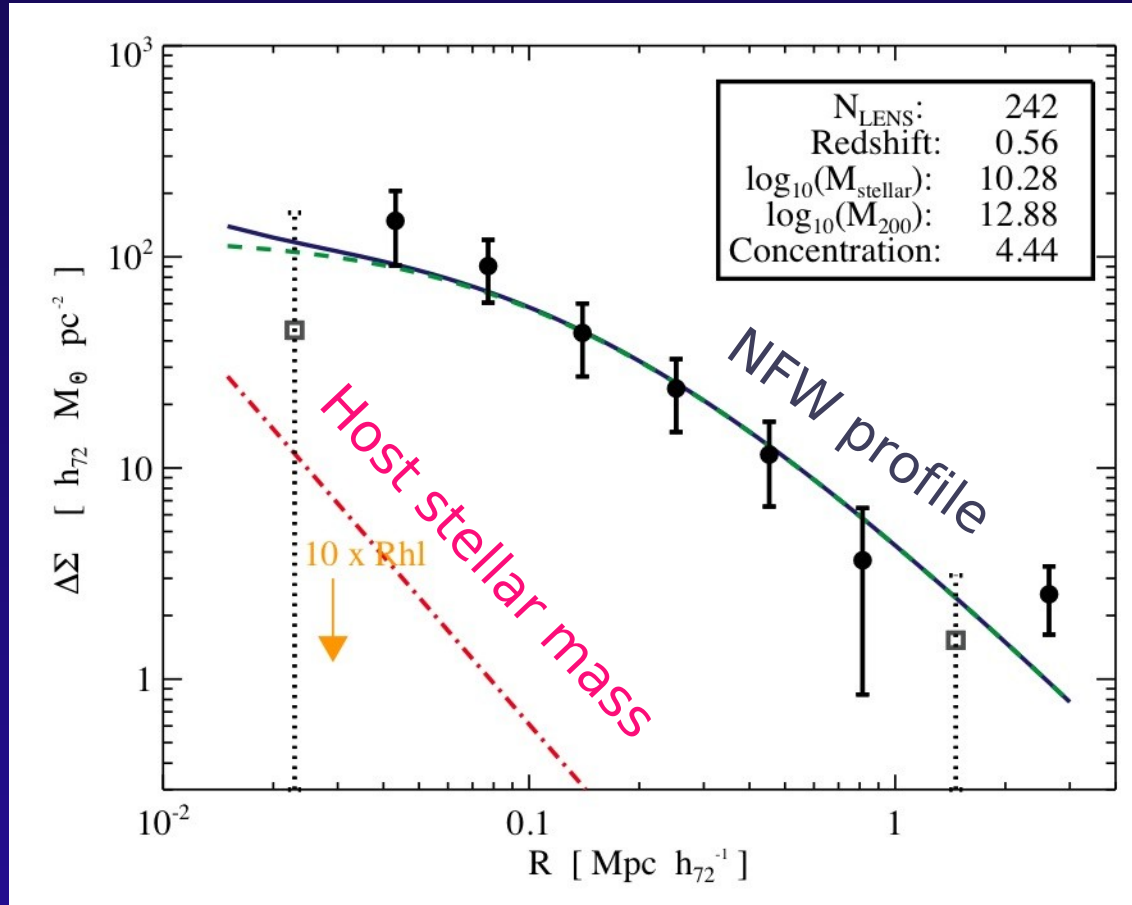


Feruglio et al. 2009 in prep.

statisti
CS

Weak Lensing around AGNs

Dark Matter halos around AGNs $\log\langle M \rangle = 12.9$, same as groups

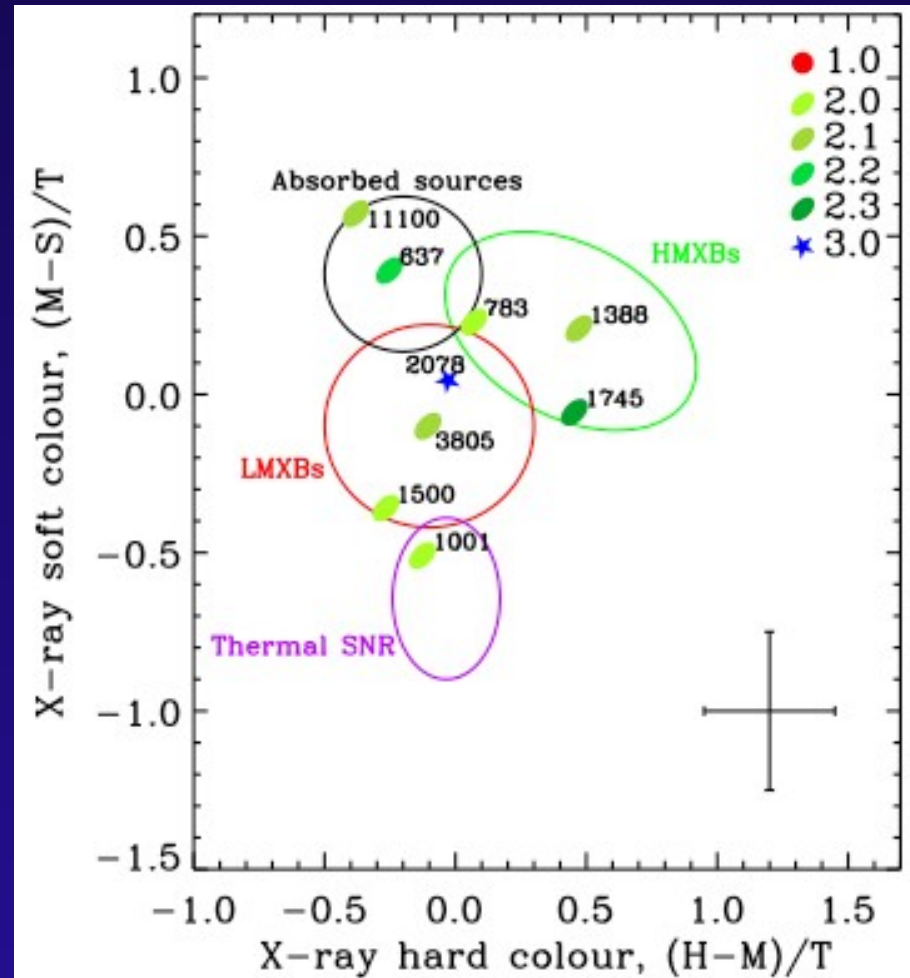
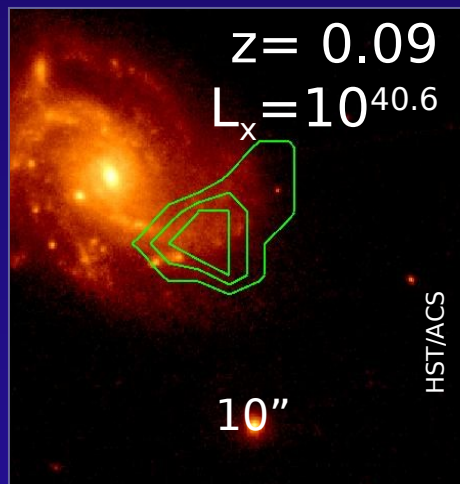
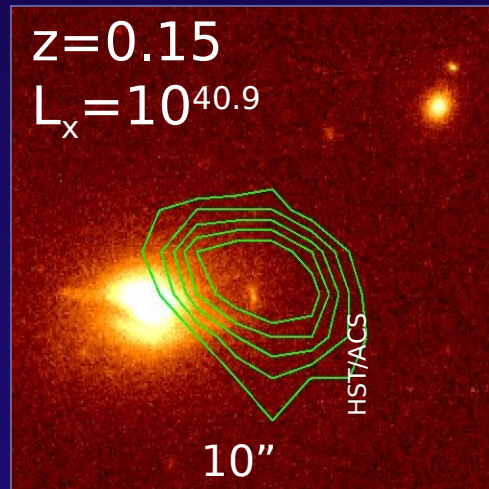


Leauthaud et al. 2009 in prep.

rare
objects

Off-Nuclear objects

16 Ultra-Luminous X-ray Sources (ULXs) - intermediate mass black holes?

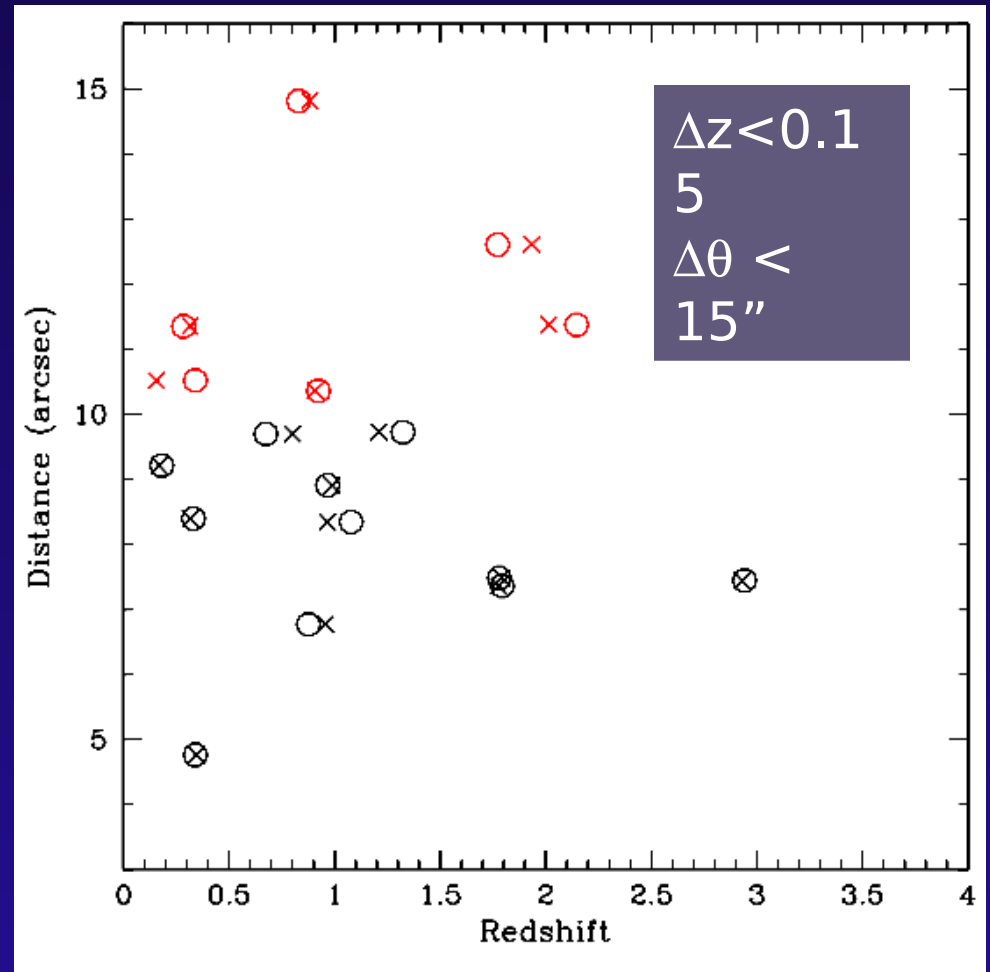
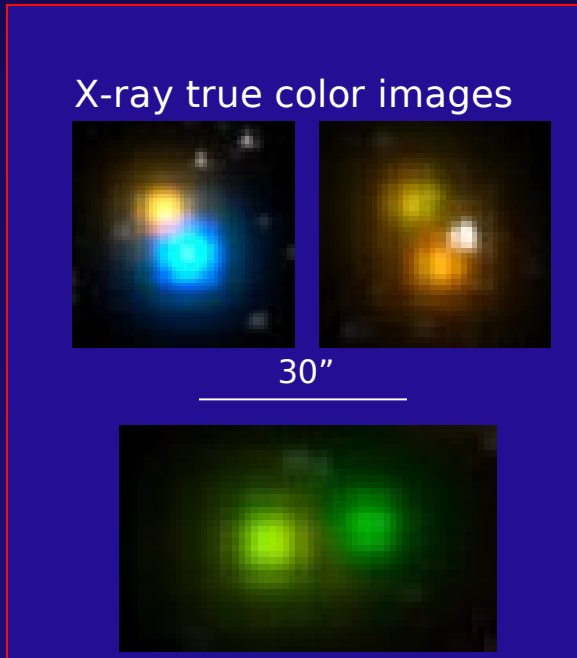


Mainieri et al. 2009, submitted

rare
objects

Close AGN Pairs

19 Physical Black Hole Pairs at few kpc separation



Civano et al. 2009, in preparation

High-z AGN

Today constraints are too loose to constrain accretion physics and cosmology (handful of AGN at $z > 4.5$ only). Both IXO and WFXT can provide breakthroughs in this field

!! provided that a PSF with HPD < 5" is

