Revealing Type II Quasars in Dust-Obscured Galaxies (DOGs) from SWIRE

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OUTLINE

2. SMBH vs Galaxy Cosmological Evolution

4. The need of a complete AGN Census: Detecting X-ray absorbed quasars (QSO 2s) at high z

6. Spitzer + X-ray Surveys: The Dust-Obscured Galaxies (DOGs)

8. X-raying DOGs

10. Future Perspectives

SMBHs vs Galaxies

A new paradigma has recently emerged suggesting a strong link between stellar assembly in galaxies and the growth of their SMBHs.

Silk & Rees 98; Hopkins+06; Di Matteo+05; Croton+06; Menci+08, …

SMBHs and star-formation (**SF**) are supposed to be intimately related by merger and feedback processes.

Active Galactic Nuclei (**AGNs**) -i.e. accretion-powered SMBHs- are not only witnesses but they are likely among leading actors of the phases of galaxy assembly

Observational evidences supporting this connection:

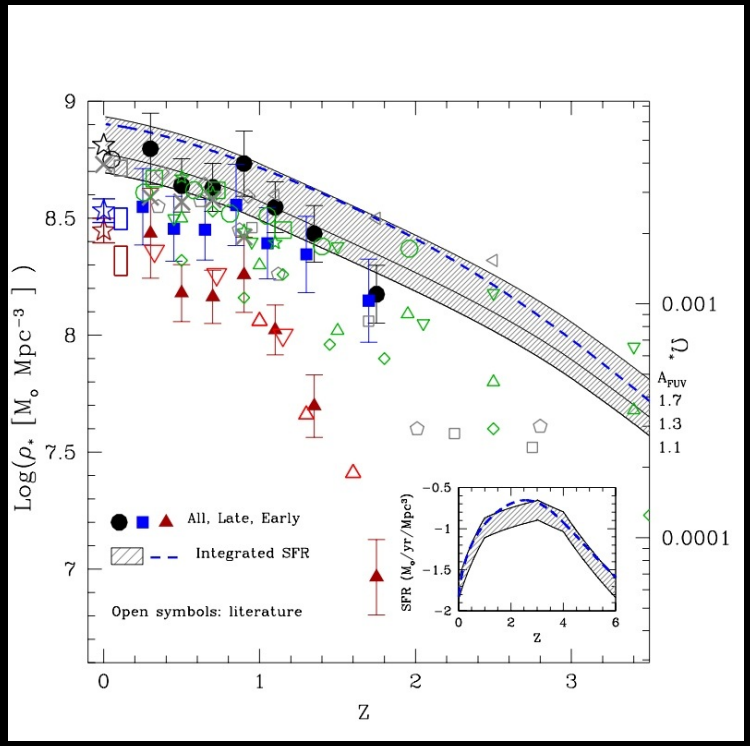
- **Virtually all (massive) spheroids host a SMBH**
  Kormendy & Richstone 95; Kormendy & Gebhardt 01
- **Tight correlations between SMBH masses and bulges properties**
  Ferrarese & Merritt 00;
- **Anti-hierchical bi-modal evolution (downsizing)**
  Franceschini+99; Fiore+03; Arnouts+07 Tresse+07; Buongiorno+07

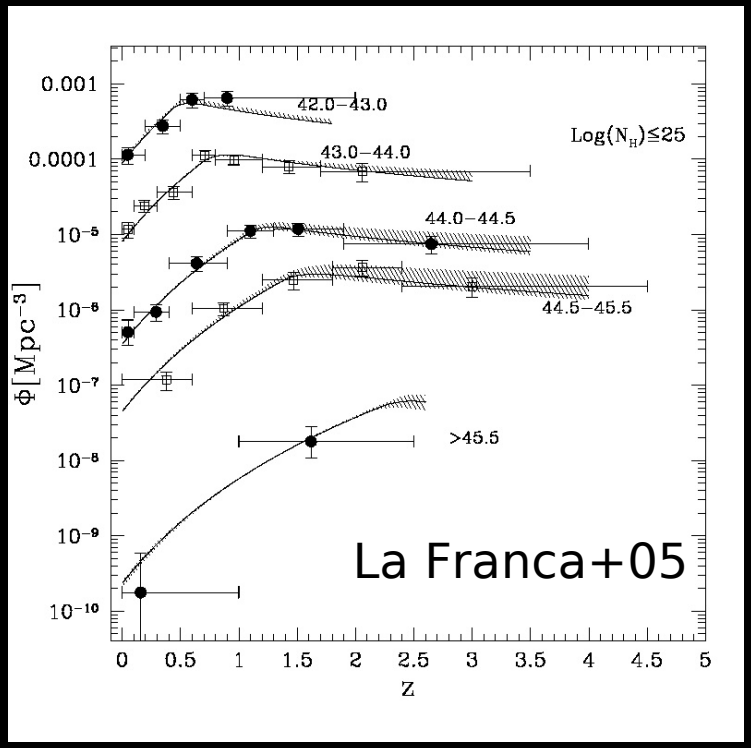
Downsizing

Galaxies: The most luminous and massive galaxies stop their SF activity at z>3, while the low-L galaxies keep producing stars until z~0.2
Tresse+07 (VIMOS VLT survey) ; **Perez-Gonzalez+08**

Distribution in color-magnitude diagram is bimodal
Red sequence: massive E/S0 galaxies
Blue peak: star-forming galaxies later than Sa

Major build-up of the red sequence 1<z<2 **Arnouts+07**





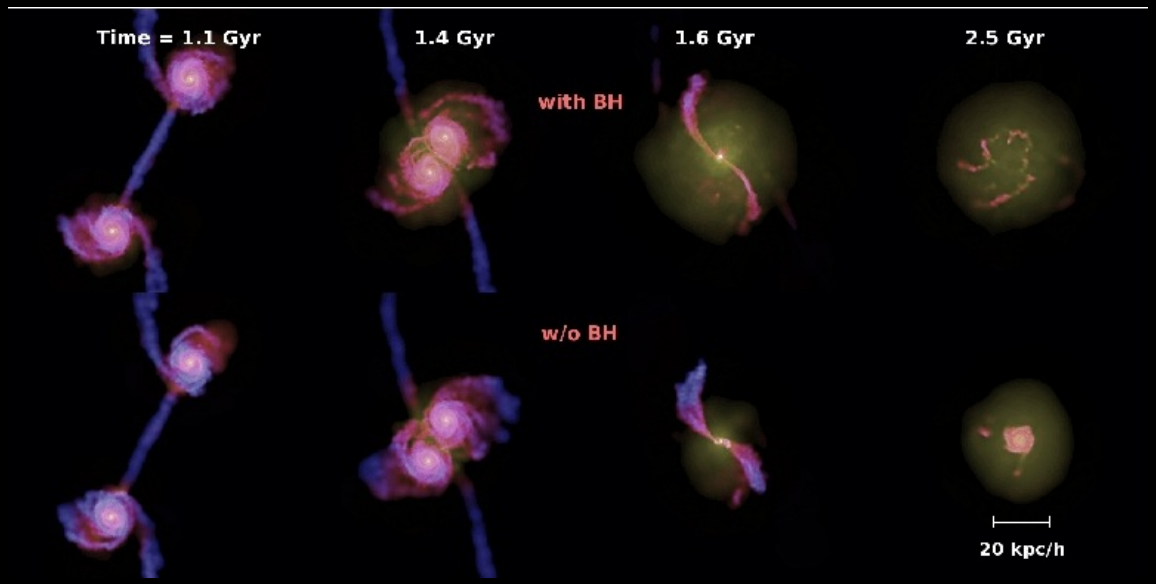
AGNs:

More Luminous AGNs form EARLIER and FASTER

Anti-hierarchical evolution **Hasinger 08, Fiore+03**

Similar results in the radio and optical band

The evolutionary sequence



Di Matteo+05; Hopkins+06; Menci+08; …

Violent galaxy-galaxy interactions

Burst of star-formation

Heavily-obscured accreting SMBH

Galaxy Merger

Critical accretion level

Feedback processes

(blow-out phase)

Optically-bright QSO

Later Time

SF & accretion is quenched

Galaxies undergo passive evolution in the Red sequence

Is this scenario correct?

Page+2004:

X-ray absorbed $1<z<3$ AGNs are sub-mm brighter (i.e. with stronger SF) than coeval unabsorbed AGNs

Alexander+05:

Most radio identified sub-mm galaxies host X-ray and optically obscured AGNs. Their L_{BOL} is dominated by SF

Polletta+09, Vignali+09:

Obscured and powerful Quasars with coeval strong starburst activity (SFR>500 M) at z ≈2-3.5

Major Open Issues:

Is the AGN census complete?
Relationships between AGN /SMBH growth and SF
Understanding the cause of the Downsizing?
What does (AGN) Feedback consist of?

Observational Tests:

Unbiased samples of AGNs
Obscured and luminous AGNs at *z*>1-2 where both SMBH accretion and SF activity peak

Completing the AGN census

Differences in luminosity, obscuration, accretion rates, SEDs, orientations hamper any one selection technique from reliably collecting all of them...the AGN census is still incomplete!!

•XMM & Chandra surveys are able to resolve only half of the Cosmic X-ray Bkg at >6 keV (**Worsley+05)**

•Too much SMBH relics with respect to the expectations based on Hard X-ray Luminosity Functions (**Marconi+04**)

X-ray (2-10 keV) surveys:

- **Powerful tool to select unobscured and mildly obscured AGNs**
- **Unable to collect most of the Compton-thick AGNs**

(observed <10 keV emission is a 30-1000 times fainter than the intrinsic one)

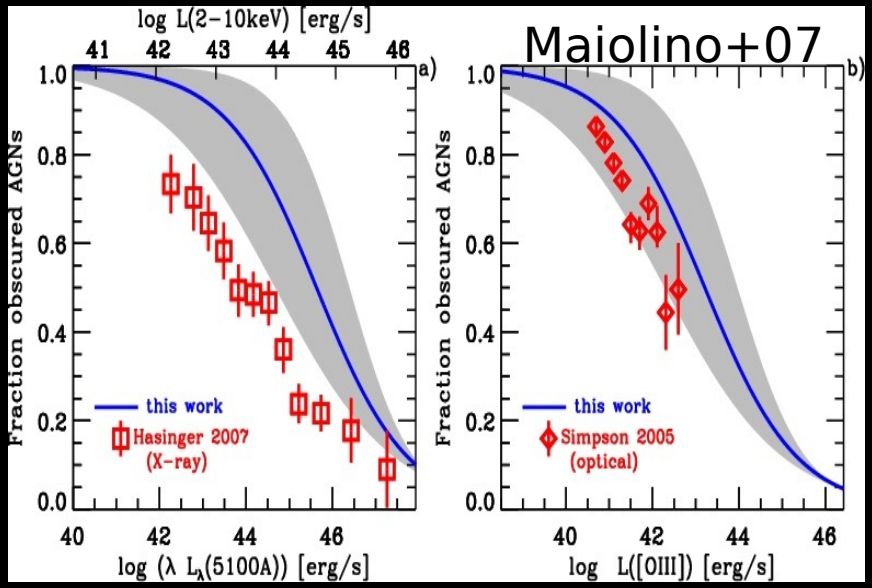
X-ray Obscured AGNs

XMM/Chandra surveys have discovered that the fraction of AGNs whose X-ray emission is absorbed (N_H>$10^{22}cm^{-2}$)

(1) decreases with the X-ray luminosity (Ueda+03)

(2) increases with the redshift (La Franca+05; Hasinger08)

(1)



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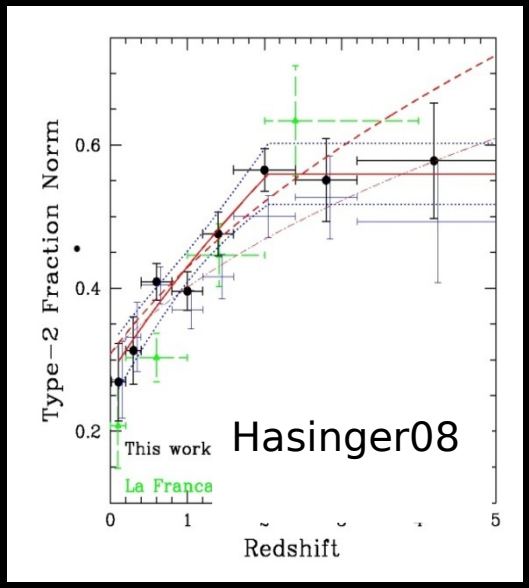


…BUT

Detection & Identification of Obscured AGNs (especially at high z) is VERY difficult

Are those trends real or just due to selection biases?

Spitzer & Mid-IR surveys

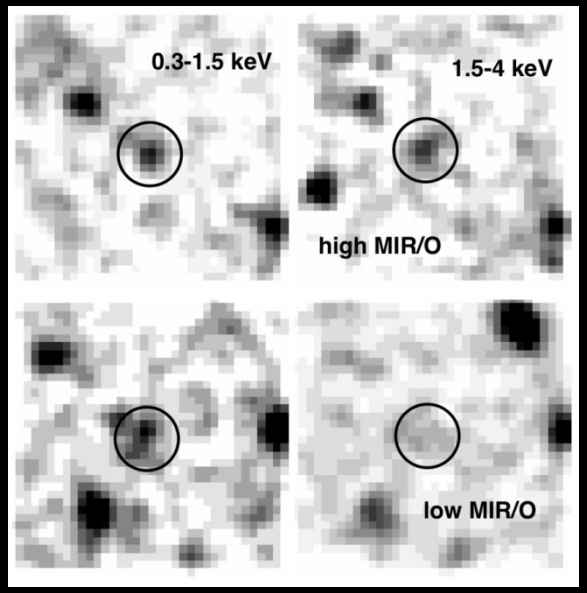
Mid-IR (3-30μ m) SPITZER surveys:

- **very efficient as absorbed opt/UV/X-ray AGN light is thermally re-emitted by the obscuring material at these wavelenghts**
- **Capable of identifying the heavily obscured AGNs missed in X-rays**

COMBINING RADIO/OPTICAL/X-RAYs & MIR
TO MINIMIZE THE EFFECTS OF OBSCURATION

e.g. Martinez-Sansigre+05;Lacy+04;Polletta+06;Yan+07;Fiore+08

The discovery of the DOGs (MIR/O>1000)



Fiore et al. 2008a,b: Selected sources with MIR/O>1000 & R-K>4.5 from CDFS and COSMOS

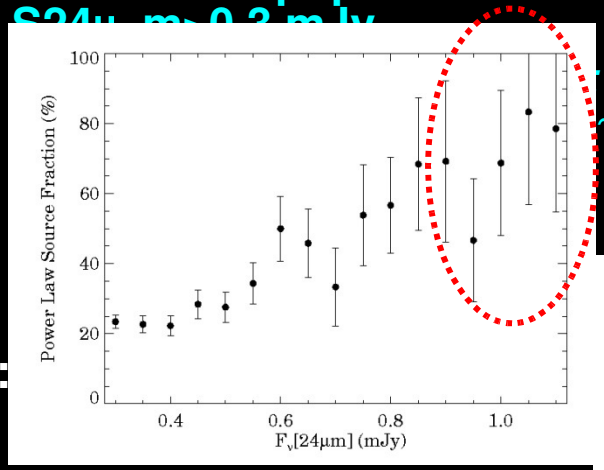
Stacking of X-ray undetected sources suggests the presence of Compton-thick AGNs (For similar results, see also: Daddi+07; Polletta+06,+08; Georgantopolous+08)

Dey et al. 2008:

Selected a population of DOGs with MIR/O>1000 &

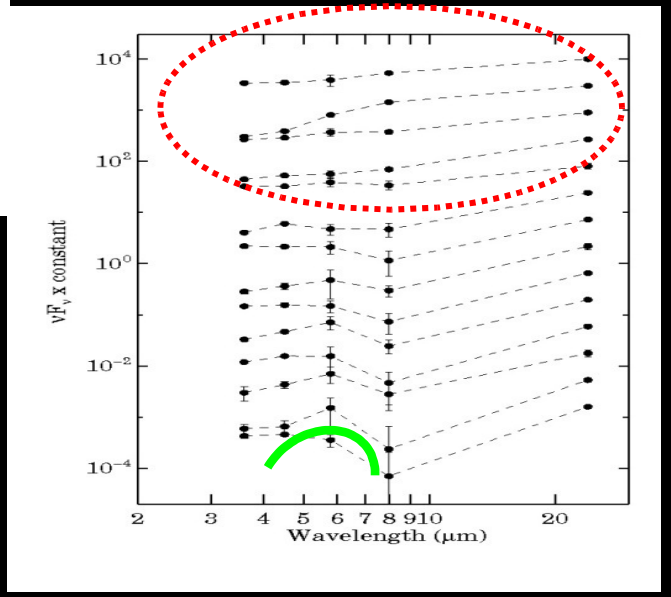
redder than typical local

~2



DOGs come in two flavors:

- **Bump DOGs: dominant at S(24μm)<1mJy; Starburst-powered (bump from 1.6 μm stellar peak)**
- **Extreme (aka Power-Law) DOGs: dominant at S(24μm) >1mJy; AGN-powered**



X-raying DOGs

Our work:

Goal: First accurate investigation of the X-ray spectral properties of EDOGs

Issue to be answered: Do EDOGs host X-ray obscured Quasars, i.e. QSO 2s?

Method: Hunting for EDOGs in SWIRE

The Spitzer SWIRE survey (Lonsdale+03) offers an unique opportunity:

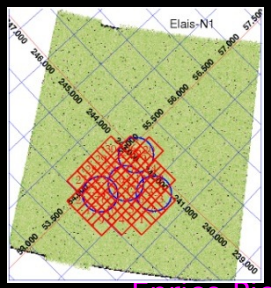
50 deg2 with medium-deep MIR coverage + multi-λ follow-ups

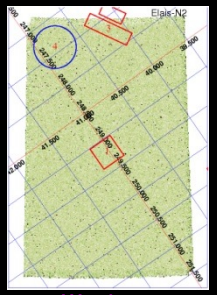
Large area: to collect luminous objects with low space density

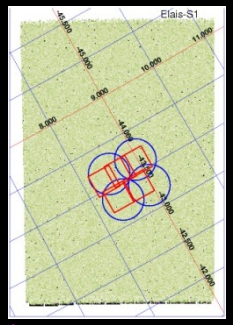
Redshift: to estimate Luminosity and intrinsic N_H

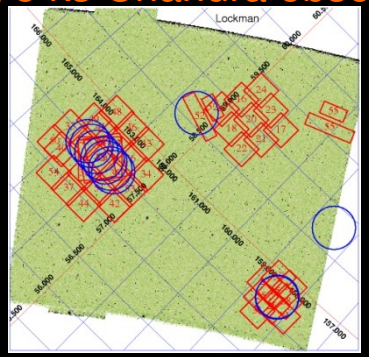
X-ray coverage: ~6 deg^2

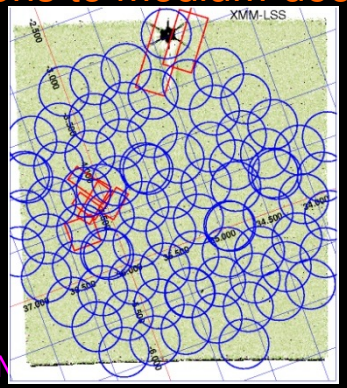
But…quite inhomogeneous: from snap-shot 5 ks Chandra observations to medium-deep XMM exposures of 50 ks











X-raying DOGs

Our work:

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Issue to O 2s?

Method:

The Spitz

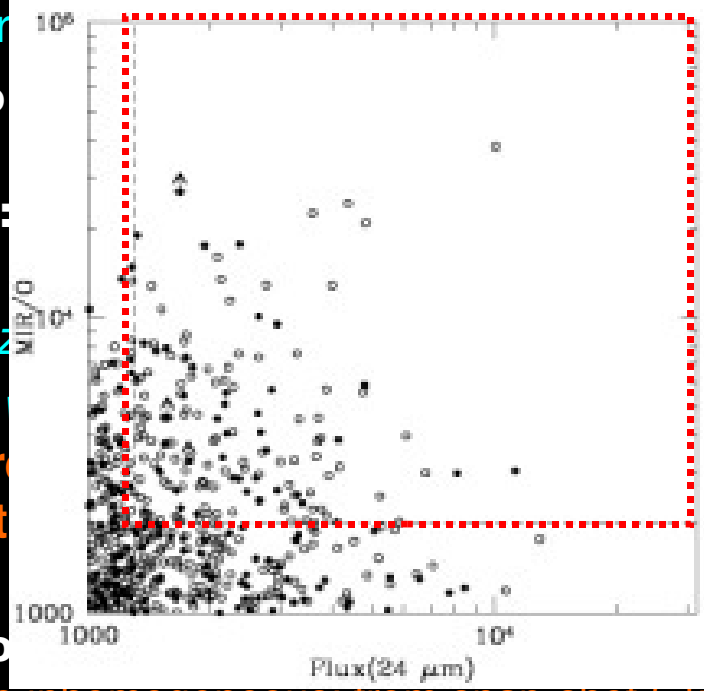
50 deg2

Large ar

Redshift

X-ray co

But…quite inhomogeneous: from snap-shot 5 ks eep XMM exposures of 50 ks



Selection criteria:

- MIR/O>2000
- $S_\nu(24\mu\ m) > 1.3mJy$

⇒**Extreme Dust-Obscured Galaxies *EDOGs***

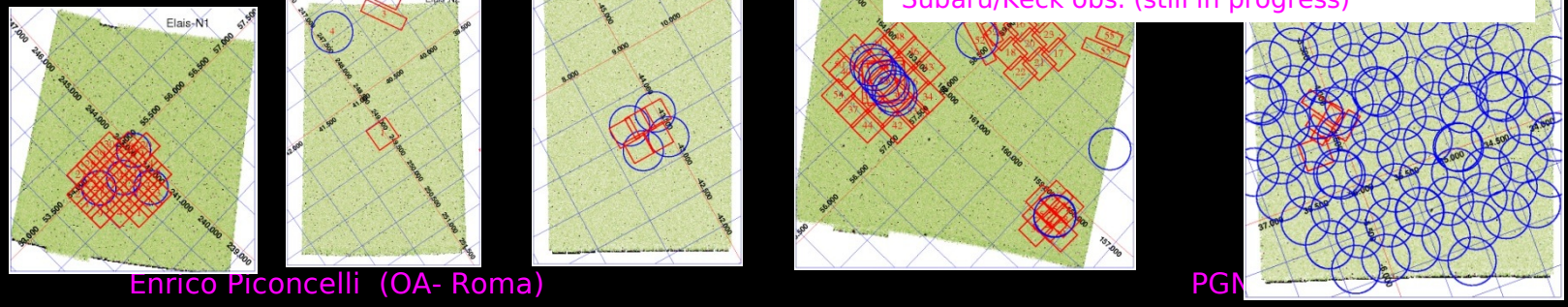
The final sample:

44 *EDOGs* selected in 6 deg² covered by XMM/Chandra obs

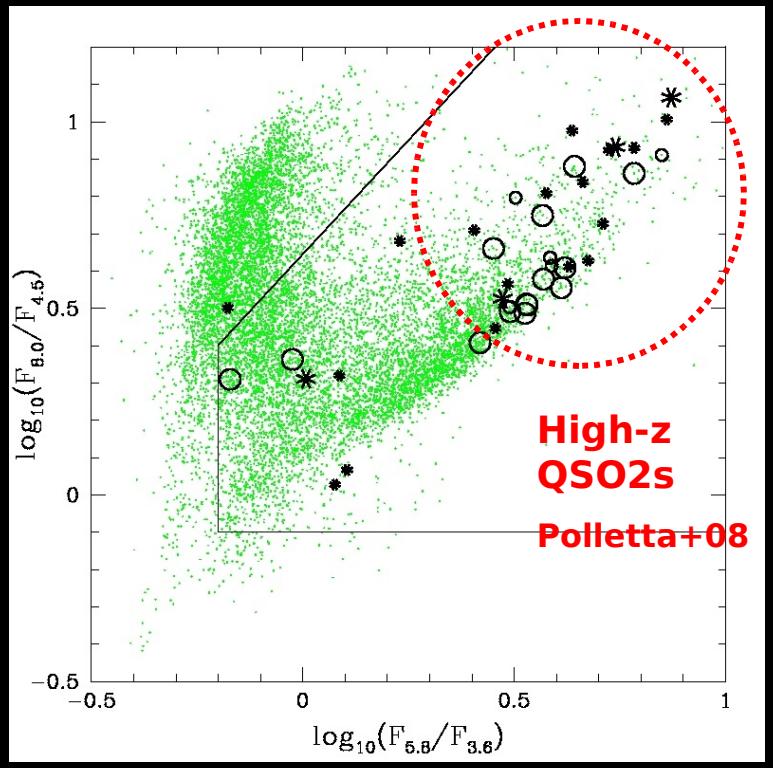
The vast majority of spectroscopic and photometric redshifts are $0.7 \leq z \leq 2.5$

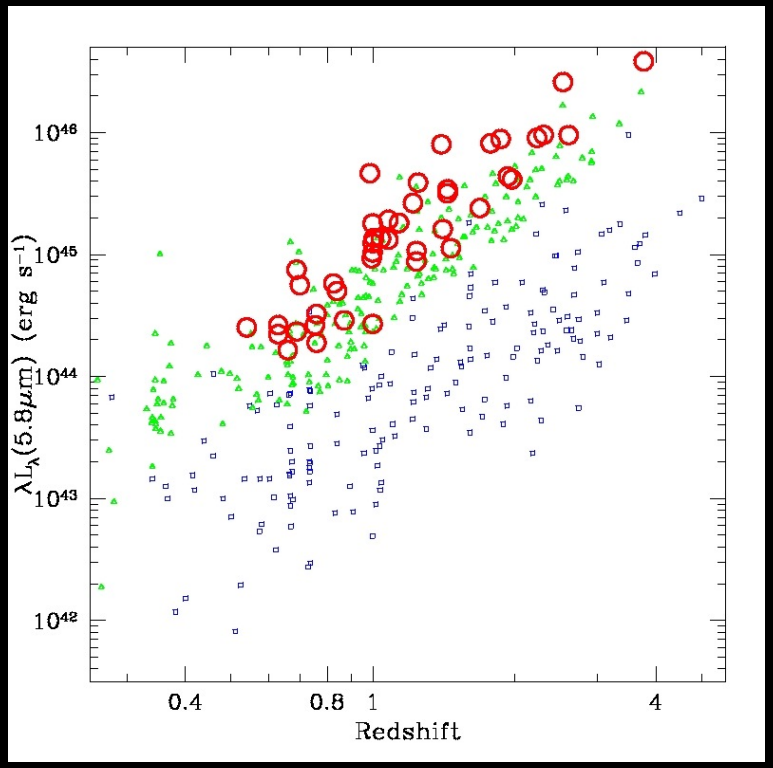
Rowan-Robinson+08; Weedman+06;

Subaru/Keck obs. (still in progress)



MIR properties of EDOGs





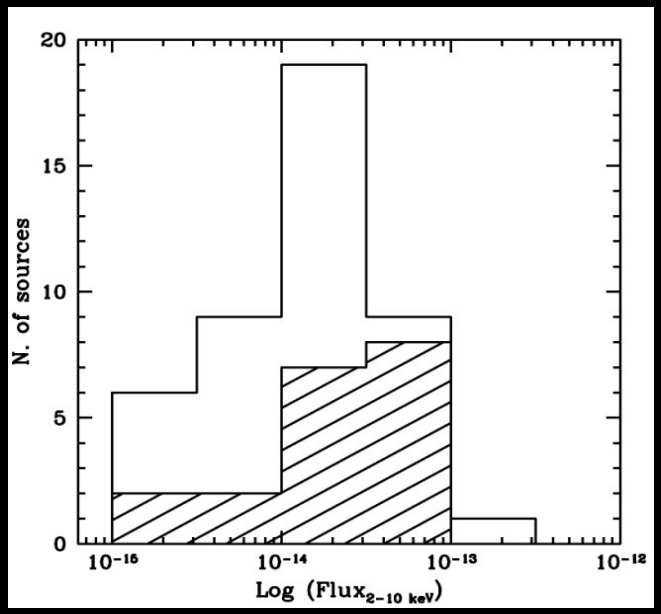
- Green points are SWIRE sources with S24μ m >1mJy

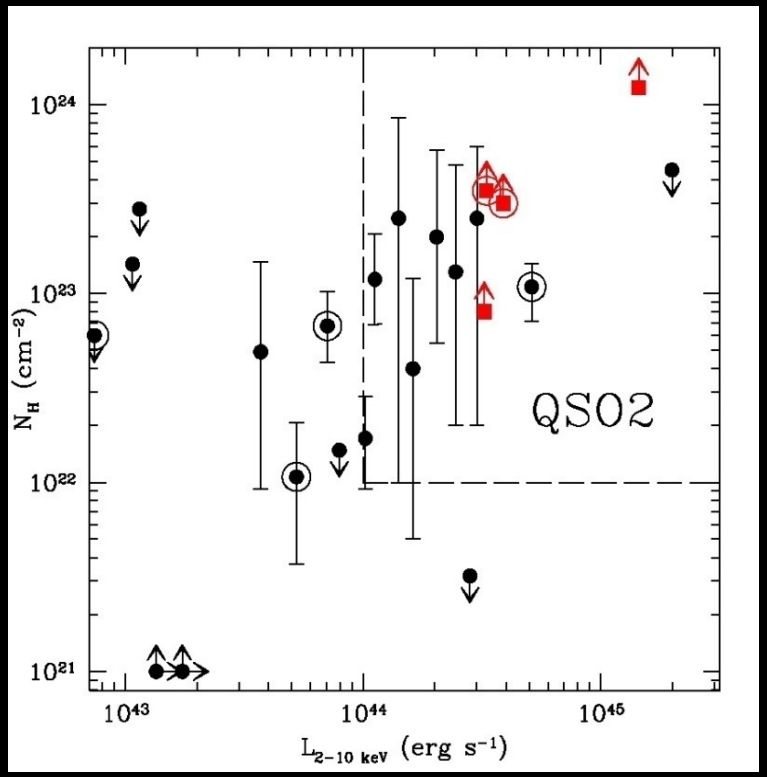
O Open circles are EDOGs with Nh estimate

* Asterisks are EDOGs without Nh estimate

~All EDOGs fall in the AGN region of the MIR color-color diagram (Lacy+04) Most of them show extreme colors as the high-z luminous obscured QSOs in Polletta+08

The X-ray view of EDOGs





>75% are X-ray obscured (15%)*

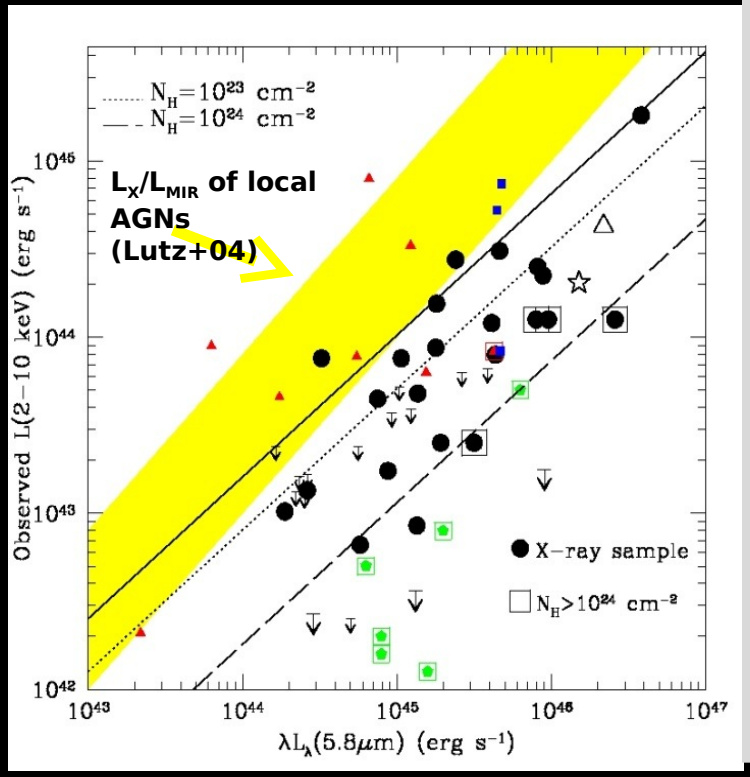
55% are QSO2s (5%)*

13% are Compton-thick QSO2s

**Control sample of sources selected regardless their MIR/O properties as in X-ray Surveys*

MIR selection + Large area → very efficient in finding out high-z QSO2s

X-ray undetected EDOGs

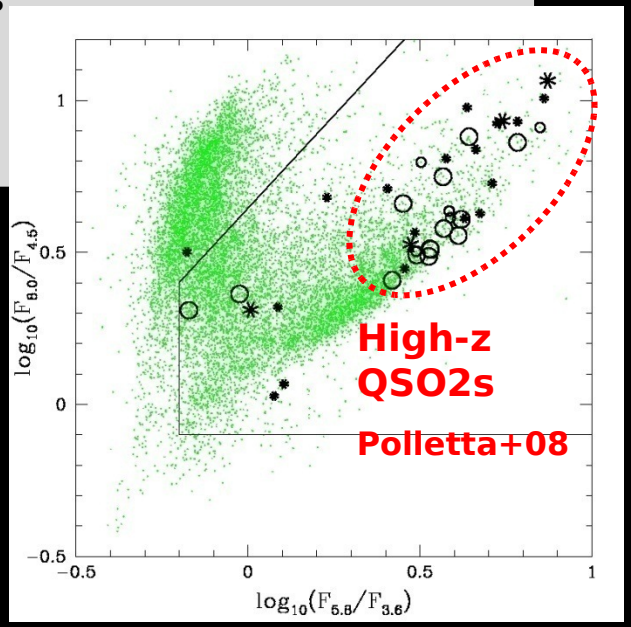


Black circles EDOGs

Green Pentagons CT AGNs *Alexander+08*

Red Triangles X-ray-selected QSO2s *Sturm+07*

Solid Line: Our L_X – L_{MIR} relationship similar to the results obtained by Maiolino+07 for high-z, $\lambda L(5100Å)>10^{46}$ QSOs



For 15 X-ray undetected EDOGs with extreme MIR colors, i.e.Power-Law sources (= AGNs), we estimate the N_H comparing the observed luminosity with the intrinsic one from the L_X-L_{MIR}

⇒93% are X-ray obscured

⇒27% are Compton-thick ($N_H \geq 10^{24}$ cm^{-2})

Enrico Piconcelli (OA Roma)

EDOGs & QSO evolution

EDOGs host X-ray heavily obscured Quasar at z≥1

Lanzuisi+09, Fiore+08

Bump DOGs

- Faint S_ν(24μm)
- PAH-dominated MIR emission
- X-ray SB-dominated w/faint AGN
- Morphology:early-state mergers

Dey+08,
Melbourne+09,
Desay+09,
Bussman+09

Power-Law/Extreme DOGs

- Bright S_ν(24μm)
- PL-dominated MIR emission
- Strong Si absorption
- X-ray obscured Powerful AGNs
- Morphology: Late-state mergers
- More MIR luminous → More compact

EDOGs may represent the early dust-enshrouded phase invoked by the models of QSO evolution

Gas-rich mergers – (E)DOGs – QSOs – massive galaxies evolutionary link ??

Initial stage of feedback activity??

Future Work & Conclusions

X-ray

- Observing complete samples of EDOGs
- Deeper observations of the most interesting EDOGs

→ XMM-Newton AO8:
1 peculiar EDOG for 80 ks

Optical follow-up

- Complete the optical ID. and z
- X-ray vs. Opt. Classification

Far-IR follow-up with Hershel

- **evaluating the contribution of SF activity to the L_{BOL}**
- **Completing the SED (i.e. sub-mm obs.)**

We selected a sample of 44 SWIRE galaxies with extreme MIR/O flux ratios (MIR/O>2000) and S_{24} >1.3 mJy: EDOGs

- **Spectroscopic and Photometric redshifts are 0.8<z<3**
- **Many (>50%) of the X-ray detected sources are QSO2s**
- **~20% are promising Compton-thick QSO2s candidates**

We demonstrate that our MIR criterion applied to a large area survey is very efficient in finding out a large number of X-ray absorbed QSOs

Lanzuisi, Piconcelli, Fiore et al. 2009, *A&A 498, 67*