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Obscured accretion from AGN surveys

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Abstract. Recent models of super-massive black hole (SMBH) and host galaxy joint evolution predict the presence of a key phase where accretion, traced by obscured Active Galactic Nuclei (AGN) emission, is coupled with powerful star formation. Then feedback processes likely self-regulate the SMBH growth and quench the star-formation activity. AGN in this important evolutionary phase have been revealed in the last decade via surveys at different wavelengths. On the one hand, moderate-to-deep X-ray surveys have allowed a systematic search for heavily obscured AGN, up to very high redshifts (z≈5). On the other hand, infrared/optical surveys have been invaluable in offering complementary methods to select obscured AGN also in cases where the nuclear X-ray emission below 10 keV is largely hidden to our view. In this review I will present my personal perspective of the field of obscured accretion from AGN surveys.

1. Introduction

One of the main science goals of modern observational cosmology is devoted to understand how galaxies and SMBHs at their centers grow together. Their close link leaves imprints in several relations observed in the local Universe between the mass of the black holes and the properties of the host galaxies (e.g., their velocity dispersion; Gebhardt *et al.* 2000; Ferrarese & Merritt 2000). The emerging picture is that AGN are the key to understand the nature of such close connection, since the mass function of local SMBHs can be reasonably explained by the growth of seed black holes (whatever the origin of such seeds is) during AGN phases (e.g., Soltan 1982; Marconi *et al.* 2004).

The entire picture, related to the so-called AGN-galaxy co-evolution scenario, has been presented in many works over the last decade, and has been perfectly synthesized in Fig. 1 of Hopkins *et al.* (2008), along the path traced by the original suggestion of Sanders *et al.* 1988 (see also Sanders & Mirabel 1996). Concisely, current quasar/host galaxy co-evolution models predict the existence of a dust-enshrouded phase associated with rapid SMBH growth and active star formation, largely triggered by multiple galaxy mergers and encounters (e.g., Silk & Rees 1998; Di Matteo *et al.* 2005; Menci *et al.* 2008; Zubovas & King 2012; Lamastra *et al.* 2013). This phase is likely associated to obscured AGN growth in strongly star-forming (sub-millimeter) galaxies (e.g., Alexander *et al.* 2005). Finally, massive quasar-driven outflows blow away most of the cold gas reservoir, creating a population of "red-and-dead" gas-poor elliptical galaxies (e.g., Cattaneo *et al.* 2009).

Support to this scenario comes from observations of wide-angle molecular outflows extending few kpc from the nucleus in some quasars hosted in ultra-luminous infrared galaxies; these systems, typically characterized by mass loss rates much larger than the ongoing star-formation rate (e.g., Feruglio *et al.* 2010; Sturm *et al.* 2011; Rupke & Veilleux 2013; Cicone *et al.* 2014), are observed up to very high redshifts (Maiolino *et al.* 2012; Borguet *et al.* 2013). Similarly, observations of powerful outflows in neutral and ionized gas have also been collected over the past few years (e.g., Nesvadba *et al.* 2008; Alexander *et al.* 2010; Harrison *et al.* 2012). This feedback process ascribed to quasars is most certainly related to radiation-driven winds and is often invoked to explain why SMBHs and galaxies stop growing at a certain phase of their life; for a more comprehensive discussion on this issue, see the review by C. M. Harrison (this Volume). Evidences for ultra-fast outflows (with velocities typically up to 0.1–0.4c) have been recently observed in X-rays in a sizable sample of AGN, both in the local Universe (e.g., Tombesi *et al.* 2010, 2011, 2012; Gofford *et al.* 2013; Reeves *et al.* 2003) and at high redshift (e.g., Chartas *et al.* 2002, 2007; Saez *et al.* 2009). The connection between molecular and highly ionized gas is, however, from from being assessed, and will constitute undoubtedly one of the prime science goals of the coming years using *ALMA* and *IRAM* facilities at long wavelengths and *Chandra* and XMM-*Newton* in the X-ray domain.

According to the scenario described above, the main trigger mechanism of BH accretion and growth is ascribed to galaxy mergers and interactions, at least in the most luminous and massive systems. Most of their mass is assembled in short periods (≈10–100 Myr) of "bursting" nuclear and star-forming activity, while the bulk of galaxies and SMBHs grow their mass in a secular (i.e., "smooth") mode over timescales of Gyrs (e.g., Daddi *et al.* 2007a; Hickox *et al.* 2009). This picture has recently been confirmed by *Herschel* surveys, showing a distinction between the bulk of galaxies growing quietly (in the so-called "main sequence") and the minority of the galaxy population whose growth happens mostly during events of mergers of gas-rich galaxies in the so-called "starburst mode" (e.g., Elbaz *et al.* 2011; Rodighiero *et al.* 2011; see also Rosario *et al.* 2013).

As a natural consequence of the merger scenario, a key phase in the AGN and galaxy life is when large amounts of gas are funneled to the center, thus inducing both obscured accretion and star formation (e.g., Treister *et al.* 2010). Significant efforts have been made recently to search for and characterize, as much as possible, the most heavily obscured AGN and quasars, dubbed Compton thick, characterized by column densities above 1.5×10^{24} cm^{-2} (see Comastri 2004 for a review); such absorbers strongly limit the possibility for these sources of being detected at energies below 10 keV (where sensitive X-ray imaging instruments are currently operative). Therefore, in order to provide a census as complete as possible of this source population, a multi-wavelength synergistic approach is needed.

In this review I will focus on some aspects and methods of investigation that I think are important in the quest for heavily obscured AGN. As such, this proceeding is not meant to provide an exhaustive view of this topic. Further and, possibly, alternative approaches in this research field and consequences for AGN synthesis models of the X-ray background (XRB) are addressed by other authors in this Volume (e.g., A. Barger, A. Del Moro, S. Juneau, A. Levenson, S. Mateos, L. Spinoglio, D. Stern, E. Treister, Y. Ueda).

2. Searching for heavily obscured AGN

The problem of finding heavily obscured AGN and quasars can be tackled following various prescriptions and adopting different approaches. The bad news is that there is no way to obtain a complete census of this AGN population either using single-band observations or a unique selection method/criterion. The good news is that the multi-wavelength observing campaigns which characterize most of the current surveys offer a unique possibility to detect the most obscured AGN, up to very high redshifts. Adopting several selection criteria and keeping in mind the observational biases intrinsic to each detection band are what we need in the future to infer the demographics of these elusive AGN and use them to provide "boundary" conditions and useful constraints to AGN/galaxy co-evolution models.

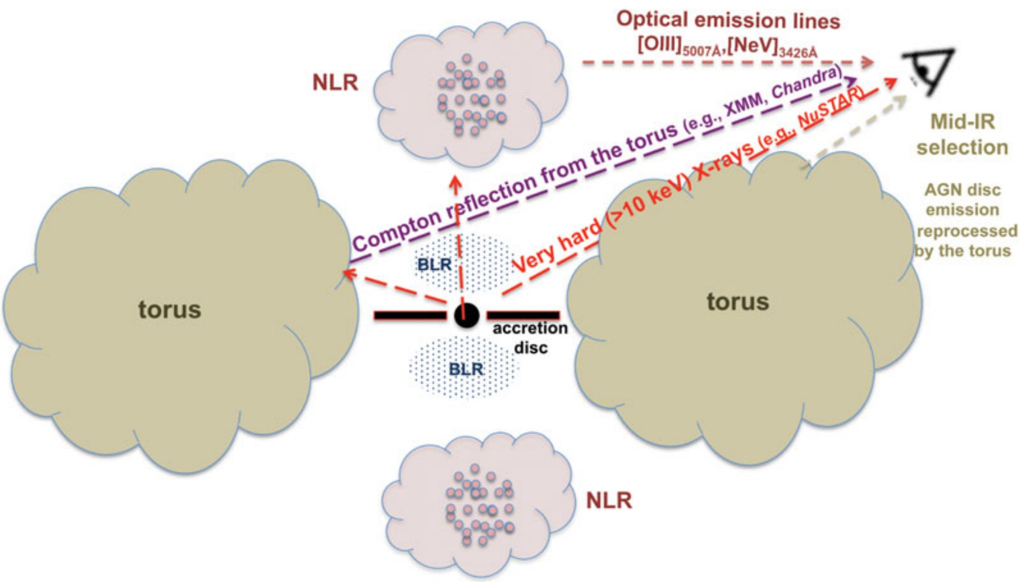

Figure 1. Schematic view of AGN (not in scale). Emphasis is given to the emission components which, at different wavelengths, allow for the detection of obscured AGN. BLR and NLR stand for broad-line region and narrow-line region, respectively.

In the following, I will try to elucidate some detection techniques adopted to find obscured AGN, which are schematized in Fig. 1. In particular, I am referring to methods related to X-ray (§2.1), mid-infrared (mid-IR; §2.2) and optical selection (§2.3).

2.1. *Hard X-ray surveys*

According to the unified model for AGN (Antonucci 1993), the X-ray emission, once it intercepts the obscuring material (i.e., the torus; see Fig. 1), can be profoundly depressed in the X-ray band. In particular, if the optical depth for Compton scattering ($\tau = N_H \times \sigma_T$) does not exceed values of the order of "*a few*", X-ray photons with energies higher than 10–15 keV are able to penetrate the obscuring material and reach the observer. For higher values of τ, the entire X-ray spectrum is depressed by Compton down-scattering and the X-ray photons are effectively trapped by the obscuring material irrespective of their energy. The former class of sources (mildly Compton thick) can be efficiently detected by X-ray instruments above 10 keV, while for the latter (heavily Compton thick) their nature may be inferred through indirect arguments, such as the presence of a strong iron Kα emission line over a flat reflected continuum. Mildly Compton-thick AGN are the most promising candidates to explain the residual (i.e., not resolved yet) spectrum of the cosmic XRB at its 30 keV peak (e.g., Worsley *et al.* 2005; Gilli *et al.* 2007; Ballantyne 2009; Treister *et al.* 2009; Moretti *et al.* 2012; Shi *et al.* 2013) but only a handful of them are known (i.e., have been classified as such beyond any reasonable doubt) outside the local Universe (e.g., Iwasawa *et al.* 2005). An unbiased census of extremely obscured AGN would require to survey the hard X-ray above 10 keV with a fairly good sensitivity. A step forward in this direction is being provided by the *Swift*/BAT and *Integral*/IBIS surveys (e.g., Tueller *et al.* 2008; Beckmann *et al.* 2009; Vasudevan *et al.* 2013), which have covered a large portion of the sky though limited to relatively bright X-ray fluxes ($\approx 10^{-11}$ erg cm^{-2} s^{-1}), hence to low redshifts, and have resolved less than 10% of the XRB. The spectral characterization of the heavily obscured AGN discovered in these shallow hard X-ray surveys often required follow-up observations with the more sensitive instruments onboard *Chandra*, XMM-*Newton* and *Suzaku* (e.g., Eguchi *et al.* 2009; Comastri *et al.* 2010; Winter *et al.* 2010; Severgnini *et al.* 2011; Burlon *et al.* 2011); this approach led to an estimate of a fraction of ≈ 10–20% of Compton-thick AGN among hard X-ray selected samples (e.g., Malizia *et al.* 2009; Burlon *et al.* 2011; Vasudevan *et al.* 2013). Data from the *NuSTAR* satellite, having imaging capabilities up to ≈ 80 keV, can shed new light on this topic at sensitivities more than a factor 100 better than those achieved by *Integral* and *Swift* (Alexander *et al.* 2013).

Deep X-ray surveys with sensitive imaging instruments (*Chandra* and XMM-*Newton*) can push the detection of Compton-thick AGN at considerably higher redshifts (e.g., $z = 4.75$, Gilli *et al.* 2011). Indications of Compton-thick material in AGN and quasars have been found by many authors, often coupled to powerful star formation (from few hundred to ≈ 1000 $M_{\odot}$/yr), mostly using the deep exposures in the *Chandra* Deep Field-South (CDF-S) provided by both *Chandra* (currently 4 Ms – Xue *et al.* 2011 – close to be extended to 7 Ms) and XMM-*Newton* (≈ 3 Ms; Ranalli *et al.* 2013); see, e.g., Tozzi *et al.* (2006); Georgantopoulos *et al.* (2009, 2013); Comastri *et al.* (2011); Feruglio *et al.* (2011); Brightman & Ueda (2012); Vito *et al.* (2013). For a significant fraction of X-ray sources found in deep fields, the signal-to-noise ratio of the spectra is limited and does not allow for a proper characterization of the source spectral complexities. Further constraints on the obscured AGN population may be derived using X-ray stacking techniques which take benefit of the good spatial resolution (primarily offered by *Chandra*) and allow exploration of considerably deeper X-ray fluxes (e.g., Xue *et al.* 2012). However, even the deepest X-ray exposures currently available miss a significant number of very obscured AGN, hence a not negligible fraction of the accretion power in the Universe.

Another interesting result which is emerging from deep X-ray surveys is related to the increasing fraction of heavily obscured quasars from z=0 to z≈3–4; a similar trend is apparently not observed in lower luminosity AGN (Iwasawa *et al.* 2012; Vito *et al.* 2013). Since the fraction of AGN in mergers seems to increase with the bolometric luminosity (Treister *et al.* 2012), we may expect that at high redshift, when the merger rate was higher, a larger gas fraction (producing obscuration) was available in galaxies. The planned extension of *Chandra* observations in the CDF-S, coupled to very deep infrared data (e.g., CANDELS), will hopefully allow us to explore this hypothesis at very high redshifts in a couple of years.

2.2. *Mid-infrared selection*

The mid-IR regime offers much potential for discovery of heavily obscured AGN, since any primary AGN continuum (i.e., disc emission) that is absorbed must ultimately come out at these wavelengths after being thermally reprocessed by the torus (see Fig. 1). Thus, sources with weak emission in the optical band (because of extinction) and relatively bright mid-IR emission can be counted as heavily obscured AGN candidates, unless a significant contribution in the mid-IR comes from star-formation processes (PAH features and continuum emission). This probably "basic" high mid-IR/optical flux-ratio selection method found support in many works in the era of the *Spitzer* observatory (e.g., Martínez-Sansigre *et al.* 2005; Houck *et al.* 2005; Weedman *et al.* 2006), and allowed Dey *et al.* (2008) to define a new class of sources at $z \approx 2$, the dusty obscured galaxies (DOGs), having $F_{24\mu\mathrm{m}}/F_R > 1000$. Among these, we may expect some of the most obscured AGN, especially if a selection at $F_{24\mu\mathrm{m}} > 1$ mJy is adopted to limit

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the contamination from star-forming galaxies (e.g., Sacchi *et al.* 2009). This selection is different from those allowed by the widely adopted mid-IR color-color diagrams (e.g., Lacy *et al.* 2004; Stern *et al.* 2005; see also Donley *et al.* 2012), where separating the most heavily obscured AGN from the remaining source populations is not a trivial job (e.g., Castelló-Mor *et al.* 2013). However, only X-ray data have been able to provide the smoking gun of the truly Compton-thick nature for a fraction of the high mid-IR/optical flux-ratio sources (e.g., Polletta *et al.* 2006; Lanzuisi *et al.* 2009; Georgantopoulos *et al.* 2011; see also Severgnini *et al.* 2012). Furthermore, X-ray stacking analyses have allowed to place observational constraints, for the first time, to the space density of Compton-thick AGN at high redshifts ($z \approx 2-3$; Daddi *et al.* 2007b; Fiore *et al.* 2008, 2009; Bauer *et al.* 2010; Alexander *et al.* 2011; but see also Georgakakis *et al.* 2010).

Extension of the mid-IR search for heavily obscured AGN is within the capabilities offered by *WISE*, as shown by Mateos *et al.* (2013) and D. Stern (this Volume).

2.3. *Optical selection*

The selection of obscured AGN using optical spectroscopy proceeds primarily through the detection of high-ionization emission lines, e.g., [O III]5007Å and [Ne V]3426Å. These lines, being produced in the narrow-line region (NLR), do not suffer from extinction from the torus and are considered good proxies of the nuclear intrinsic power (see Fig. 1). Applying the relation between [O III] and 2–10 keV emission (e.g., Mulchaey *et al.* 1994; Heckman *et al.* 2005; Panessa *et al.* 2006) to the sample of narrow-line AGN from the Sloan Digital Sky Survey of Zakamska *et al.* (2003) led some authors (e.g., Vignali *et al.* 2006, 2010; Ptak *et al.* 2006) to the discovery of about a dozen of Compton-thick AGN candidates. These studies allowed a first estimate of the space density of this obscured AGN population at $z \approx 0.3 - 0.8$. According to Gilli *et al.* (2007, 2013) XRB models, the fraction of XRB emission at 20 keV produced by Compton-thick AGN and still "missing" has a peak at $z \approx 0.7$ and is mostly due to Seyfert-like objects, with intrinsic 2–10 keV luminosity below 10^{44} erg s^{-1}. Moving these investigations to slightly higher redshifts requires the use of the [Ne V] emission line, which has the advantage of being an unambiguous marker of AGN (with a ionization potential of 97 eV vs. 54 eV of [O III]) but is ≈ 9 times weaker than [O III] and suffers from stronger extinction. Calibrating the X-ray-to-[Ne V] luminosity ratio on a sample of local AGN, Gilli *et al.* (2010) show that values < 15 are highly indicative of Compton-thick obscuration. How effective this line is in finding Compton-thick AGN has been recently confirmed by Mignoli *et al.* (2013), where narrow-line AGN were selected from the zCOSMOS survey and X-ray coverage was provided by *Chandra* (Vignali *et al.*, in preparation). About 40% of the original ≈ 70 candidates are consistent with being Compton thick (in line with Gilli *et al.* 2007 model). We note, however, that optical spectroscopy, because of extinction within the NLR, is far from offering a complete census of obscured AGN (see §3.3 of Mignoli *et al.* 2013). Further insights into the properties of these [Ne V]-selected Compton-thick AGN will come out by using their mid-IR emission as another proxy of the nuclear emission (e.g., Gandhi *et al.* 2009) to be compared to the observed X-ray luminosity.

3. Conclusions

Obscured AGN growth is a key phase in SMBH/galaxy co-evolution models. As the census of such objects is difficult, especially at high redshifts, a multi-wavelength synergistic approach is needed, requiring deep X-ray exposure, mid-IR data and, possibly, optical/near-IR spectroscopy. Whatever the adopted selection method is, X-rays represent a powerful and fundamental probe through direct X-ray spectroscopy and stacking analysis.

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References

Alexander, D. M., Smail, I., Bauer, F. E., *et al.* 2005, *Nature*, 434, 738
Alexander, D. M., Swinbank, A. M., Smail, I., *et al.* 2010, *MNRAS*, 402, 2211
Alexander, D. M., Bauer, F. E., Brandt, W. N., *et al.* 2011, *ApJ*, 738, 44
Alexander, D. M., Stern, D., Del Moro, A., *et al.* 2013, *ApJ*, 773, 125
Antonucci, R. 1993, *ARA&A*, 31, 473
Ballantyne, D. R. 2009, *ApJ*, 698, 1033
Bauer, F. E., Yan, L., Sajina, A., & Alexander, D. M. 2010, *ApJ*, 710, 212
Beckmann, V., Soldi, S., Ricci, C., *et al.* 2009, *A&A*, 505, 417
Borguet, B. C. J., Arav, N., Edmonds, D., Chamberlain, C., & Benn, C. 2013, *ApJ*, 762, 49
Brightman, M. & Ueda, Y. 2012, *MNRAS*, 423, 702
Burlon, D., Ajello, M., Greiner, J., *et al.* 2011, *ApJ*, 728, 58
Castelló-Mor, N., Carrera, F. J., Alonso-Herrero, A., *et al.* 2013, *A&A*, 556, A114
Cattaneo, A., Faber, S. M., Binney, J., *et al.* 2009, *Nature*, 460, 213
Chartas, G., Brandt, W. N., Gallagher, S. C., & Garmire, G. P. 2002, *ApJ*, 579, 169
Chartas, G., Eracleous, M., Dai, X., Agol, E., & Gallagher, S. 2007, *ApJ*, 661, 678
Cicone, C., Maiolino, R., Sturm, E., *et al.* 2014, *A&A*, 562, A21
Comastri, A. 2004, in: A. J. Barger (eds.), *Supermassive Black Holes in the Distant Universe*, (Astrophysics and Space Science Library: Kluwer), 308, 245
Comastri, A., Iwasawa, K., Gilli, R., *et al.* 2010, *ApJ*, 717, 787
Comastri, A., Ranalli, P., Iwasawa, K., *et al.* 2011, *A&A*, 526, L9
Daddi, E., *et al.* 2007a, *ApJ*, 670, 156
Daddi, E., *et al.* 2007b, *ApJ*, 670, 173
Dey, A., Soifer, B. T., Desai, V., *et al.* 2008, *ApJ*, 677, 943
Di Matteo, T., Springel, V., & Hernquist, L. 2005, *Nature*, 433, 604
Donley, J. L., Koekemoer, A. M., Brusa, M., *et al.* 2012, *ApJ*, 748, 142
Eguchi, S., Ueda, Y., Terashima, Y., Mushotzky, R., & Tueller, J. 2009, *ApJ*, 696, 1657
Elbaz, D., Dickinson, M., Hwang, H. S., *et al.* 2011, *A&A*, 533, A119
Ferrarese, L. & Merritt, D. 2000, *ApJ* (Letters), 539, L9
Feruglio, C., Maiolino, R., Piconcelli, E., *et al.* 2010, *A&A* (Letters), 518, L155
Feruglio, C., Daddi, E., Fiore, F., *et al.* 2011, *ApJ* (Letters), 729, L4
Fiore, F., Grazian, A., Santini, P., *et al.* 2008, *ApJ*, 672, 94
Fiore, F., Puccetti, S., Brusa, M., *et al.* 2009, *ApJ*, 693, 447
Gandhi, P., Horst, H., Smette, A., *et al.* 2009, *A&A*, 502, 457
Gebhardt, K., Bender, R., Bower, G., *et al.* 2000, *ApJ* (Letters), 539, L13
Georgakakis, A., Rowan-Robinson, M., Nandra, K., *et al.* 2010, *MNRAS*, 406, 420
Georgantopoulos, I., Akylas, A., Georgakakis, A., & Rowan-Robinson, M. 2009, *A&A*, 507, 747
Georgantopoulos, I., Rovilos, E., Akylas, A., *et al.* 2011, *A&A*, 534, A23
Georgantopoulos, I., Comastri, A., Vignali, C., *et al.* 2013, *A&A*, 555, A43
Gilli, R., Comastri, A., & Hasinger, G. 2007, *A&A*, 463, 79
Gilli, R., Vignali, C., Mignoli, M., *et al.* 2010, *A&A*, 519, A92
Gilli, R., Su, J., Norman, C., *et al.* 2011, *ApJ* (Letters), 730, L28
Gilli, R. 2013, *Mem. Soc. Astron. Italiana*, 84, 647
Gofford, J., Reeves, J. N., Tombesi, F., *et al.* 2013, *MNRAS*, 430, 60
Harrison, C. M., Alexander, D. M., Swinbank, A. M., *et al.* 2012, *MNRAS*, 426, 1073
Heckman, T. M., Ptak, A., Hornschemeier, A., & Kauffmann, G. 2005, *ApJ*, 634, 161
Hickox, R. C., Jones, C., Forman, W. R., *et al.* 2009, *ApJ*, 696, 891
Hopkins, P. F., Hernquist, L., Cox, T. J., & Kereš, D. 2008, *ApJS* (Supplement), 175, 356
Houck, J. R., Soifer, B. T., Weedman, D., *et al.* 2005, *ApJ* (Letters), 622, L105

Iwasawa, K., Crawford, C. S., Fabian, A. C., & Wilman, R. J. 2005, *MNRAS*, 362, L20
Iwasawa, K., Gilli, R., Vignali, C., *et al.* 2012, *A&A*, 546, A84
Lacy, M., Storrie-Lombardi, L. J., Sajina, A., *et al.* 2004, *ApJS* (Supplement), 154, 166
Lamastra, A., Menci, N., Fiore, F., *et al.* 2013, *A&A*, 559, A56
Lanzuisi, G., Piconcelli, E., Fiore, F., *et al.* 2009, *A&A*, 498, 67
Maiolino, R., Gallerani, S., Neri, R., *et al.* 2012, *MNRAS* (Letters), 425, L66
Malizia, A., Stephen, J. B., Bassani, L., *et al.* 2009, *MNRAS*, 399, 944
Marconi, A., Risaliti, G., Gilli, R., *et al.* 2004, *MNRAS*, 351, 169
Martínez-Sansigre, A., Rawlings, S., Lacy, M., *et al.* 2005, *Nature*, 436, 666
Mateos, S., Alonso-Herrero, A., Carrera, F. J., *et al.* 2013, *MNRAS*, 434, 941
Menci, N., Fiore, F., Puccetti, S., & Cavaliere, A. 2008, *ApJ*, 686, 219
Mignoli, M., Vignali, C., Gilli, R., *et al.* 2013, *A&A*, 556, A29
Moretti, A., Vattakunnel, S., Tozzi, P., *et al.* 2012, *A&A*, 548, A87
Mulchaey, J. S., Koratkar, A., Ward, M. J., *et al.* 1994, *ApJ*, 436, 586
Nesvadba, N. P. H., Lehnert, M. D., De Breuck, C., *et al.* 2008, *A&A*, 491, 407
Panessa, F., Bassani, L., Cappi, M., *et al.* 2006, *A&A*, 455, 173
Polletta, M. d. C., Wilkes, B. J., Siana, B., *et al.* 2006, *ApJ*, 642, 673
Ptak, A., Zakamska, N. L., Strauss, M. A., *et al.* 2006, *ApJ*, 637, 147
Ranalli, P., Comastri, A., Vignali, C., *et al.* 2013, *A&A*, 555, A42
Reeves, J. N., O'Brien, P. T., & Ward, M. J. 2003, *ApJ* (Letters), 593, L65
Rodighiero, G., Daddi, E., Baronchelli, I., *et al.* 2011, *ApJ* (Letters), 739, L40
Rosario, D. J., Trakhtenbrot, B., Lutz, D., *et al.* 2013, *A&A*, 560, A72
Rupke, D. S. N. & Veilleux, S. 2013, *ApJ* (Letters), 775, L15
Sacchi, N., La Franca, F., Feruglio, C., *et al.* 2009, *ApJ*, 703, 1778
Saez, C., Chartas, G., & Brandt, W. N. 2009, *ApJ*, 697, 194
Sanders, D. B., Soifer, B. T., Elias, J. H., *et al.* 1988, *ApJ*, 325, 74
Sanders, D. B. & Mirabel, I. F. 1996, *ARA&A*, 34, 749
Severgnini, P., Caccianiga, A., Della Ceca, R., *et al.* 2011, *A&A*, 525, A38
Severgnini, P., Caccianiga, A., & Della Ceca, R. 2012, *A&A*, 542, A46
Shi, Y., Helou, G., & Armus, L. 2013, *ApJ*, 777, 6
Silk, J. & Rees, M. J. 1998, *A&A* (Letters), 331, L1
Soltan, A. 1982, *MNRAS*, 200, 115
Stern, D., Eisenhardt, P., Gorjian, V., *et al.* 2005, *ApJ*, 631, 163
Sturm, E., González-Alfonso, E., Veilleux, S., *et al.* 2011, *ApJ* (Letters), 733, L16
Tombesi, F., Cappi, M., Reeves, J. N., *et al.* 2010, *A&A*, 521, A57
Tombesi, F., Cappi, M., Reeves, J. N., *et al.* 2011, *ApJ*, 742, 44
Tombesi, F., Cappi, M., Reeves, J. N., & Braito, V. 2012, *MNRAS* (Letters), 422, L1
Tozzi, P., Gilli, R., Mainieri, V., *et al.* 2006, *A&A*, 451, 457
Treister, E., Urry, C. M., & Virani, S. 2009, *ApJ*, 696, 110
Treister, E., Natarajan, P., Sanders, D. B., *et al.* 2010, *Science*, 328, 600
Treister, E., Schawinski, K., Urry, C. M., & Simmons, B. D. 2012, *ApJ* (Letters), 758, L39
Tueller, J., Mushotzky, R. F., Barthelmy, S., *et al.* 2008, *ApJ*, 681, 113
Vasudevan, R. V., Brandt, W. N., Mushotzky, R. F., *et al.* 2013, *ApJ*, 763, 111
Vignali, C., Alexander, D. M., & Comastri, A. 2006, *MNRAS*, 373, 321
Vignali, C., Alexander, D. M., Gilli, R., & Pozzi, F. 2010, *MNRAS*, 404, 48
Vignali, C., Mignoli, M., Gilli, R., *et al.*, *A&A*, in preparation
Vito, F., Vignali, C., Gilli, R., *et al.* 2013, *MNRAS*, 428, 354
Weedman, D. W., Soifer, B. T., Hao, L., *et al.* 2006, *ApJ*, 651, 101
Winter, L. M., Lewis, K. T., Koss, M., *et al.* 2010, *ApJ*, 710, 503
Worsley, M. A., Fabian, A. C., Bauer, F. E., *et al.* 2005, *MNRAS*, 357, 1281
Xue, Y. Q., Luo, B., Brandt, W. N., *et al.* 2011, *ApJS* (Supplement), 195, 10
Xue, Y. Q., Wang, S. X., Brandt, W. N., *et al.* 2012, *ApJ*, 758, 129
Zakamska, N. L., Strauss, M. A., Krolik, J. H., *et al.* 2003, *AJ*, 126, 2125
Zubovas, K. & King, A. R. 2012, *MNRAS*, 426, 2751