The AGN Paradigm: Radio-Quiet Objects

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Abstract. The current paradigm for radio-quiet AGNs is reviewed, taking into account new results from recent large-scale surveys carried out from the ground and from space. Topics include structure of the central engine, AGN demography, fueling/triggering processes, and connection between the supermassive black hole, host galaxy, circumnuclear starburst and AGN. Dependences on AGN power and lookback time are pointed out in the discussion. Suggestions for future avenues of research are mentioned in the last section.

1. Introduction

A quick search through the NASA/ADS Abstract Service indicates that more than \(\sim 5000\) papers were published over the past five years on AGNs! Clearly, a comprehensive review of this literature is well beyond the scope of the present article. The present review highlights important results from recent large-scale ground-based surveys and space missions, and describes the consequences of these results on our understanding of radio-quiet AGNs. The standard paradigm for radio-quiet AGNs is described in \S 2 along with a few key supporting observations. Important new constraints on this standard picture have been derived from recent UV/optical, infrared, and X-ray surveys; these are discussed in \S 3. In \S 4, the nature of the connection between the supermassive black hole, host galaxy, circumnuclear starburst, and AGN is briefly reviewed taking into account recent new data. The issue of AGN fueling/triggering is addressed in \S 5. A summary of the outstanding issues is given in \S 6 along with suggestions for future avenues of research.

2. The Standard Picture

Figure 1 is an idealized representation of the inner structure of radio-quiet AGNs. Direct observational support for this picture comes from the detection in a few radio-quiet AGNs of H\(_2\)O-masing disk-like structures in orbit around central masses of a few \(\times 10^6 - 10^7\) M\(_\odot\) on scales of 0.1 – 1.0 pc (\(\sim 10^5\) \(r_g\), where \(r_g = GM/c^2\) is the gravitational radius). The most convincing cases so far are NGC 4258 (Miyoshi et al. 1995), NGC 1068 (Greenhill et al. 1996; Greenhill
& Gwinn 1997; Gallimore et al. 1997, 2001), and NGC 4945 (Greenhill, Moran, & Herrnstein 1997). A survey by Braatz, Wilson, & Henkel (1997) failed to detect H$_2$O masers in Seyfert 1s, perhaps indicating a less favorable face-on disk geometry in these objects (small $N_H$ along the line of sight), as expected in the unification model of Seyfert galaxies (Fig. 1). Indirect evidence for accretion disk in radio-quiet AGNs comes from the presence of broad ($\geq 70,000$ km s$^{-1}$ in MCG–06-30-15), skewed and redshifted Fe K$\alpha$ lines in Seyfert 1s. This line probes the purported accretion disk within a few $r_g$ of the black hole (e.g., Tanaka et al. 1995; Iwasawa et al. 1996, 1999; Nandra et al. 1997; Guainazzi et al. 1999; Wilms et al. 2001; Lee et al. 2002; Fabian et al. 2002; Turner et al. 2002; see contribution by Fabian in this Volume). The presence of large-scale (photo-)ionization cones in radio-quiet AGNs is further indirect evidence for an inner disk structure in these objects (e.g., Haniff, Wilson, & Ward 1988; Pogge 1989; Tadhunter & Tsvetanov 1989; Wilson & Tsvetanov 1994; Mulchaey et al. 1996a, 1996b; Pogge et al. 2000; Veilleux 2002; Kinkhabwala et al. 2002).

Historically, spectropolarimetric studies of radio-quiet AGNs have been the main driver behind the unification model of Seyfert galaxies (e.g., Antonucci & Miller 1985; Miller, Goodrich, & Matthews 1991). But recent spectropolarimetric surveys indicate that only $\sim 30–50\%$ (i.e. not all) of Seyfert 2 galaxies harbor hidden broad-line regions (HBLRs; e.g., Tran 2001). Seyfert 2s with HBLRs tend to have larger radio-to-FIR flux ratios and warmer dust temperatures than those without (e.g., Miller & Goodrich 1990; Kay 1994; Heisler, Lumsden, & Bailey 1997; Moran et al. 2000; Tran 2001). These trends have been interpreted by some to imply the existence of two separate classes of Seyfert 2s. However, several authors have been quick to point out the importance of the orientation-dependent selection criteria used in many of these studies (e.g., Antonucci 2001; Alexander 2001; Lumsden et al. 2001; Gu & Huang 2002). Biases in luminosity, starburst contribution, and covering factor are necessarily present in these studies, so caution should be used when interpreting the results.
Recent results from near- and mid-infrared spectroscopy of radio-quiet AGNs have provided further support for the unification model. Obscured BLRs have been detected at $\sim 2 - 4 \, \mu m$ in a number of UV- and infrared-selected Seyfert 2 galaxies (e.g., Veilleux, Goodrich, & Hill 1997a; Veilleux, Sanders, & Kim 1997b, 1999b; Lutz et al. 2002). Clavel et al. (2000) also note that the weaker 7-$\mu$m continuum and larger equivalent widths of the PAH feature in Seyfert 2s relative to Seyfert 1s can be explained if the continuum in the Seyfert 2s is more strongly extinguished ($A_V = 92\pm37$ mag). Studies at near- and mid-infrared wavelengths can only probe down to $N_H \approx \text{few} \times 10^{22} \text{cm}^{-2}$, i.e. considerably smaller than the expected column density of the dusty torus in AGN. Hard X-ray observations have extended the range of column densities up to $\sim 10^{24} \text{cm}^{-2}$. Maiolino et al. (1998) and Risaliti, Maiolino, & Salvati (1999) have used BeppoSax, ASCA, and GINGA data to show that Seyfert 2 galaxies generally have larger obscuration than Seyfert 1s, as expected in the standard unification model. However, these observations do not put any constraints on the exact geometry and location of the obscuring material in Seyfert 2s (e.g., inner disk/torus vs. galaxy-scale circumnuclear material?).

Optical, UV, and X-ray observations of AGNs indicate that the simplest form of the standard picture (Fig. 1) is not tenable and must be modified to account for dependences on AGN luminosity. Optical spectroscopy of infrared-selected AGNs (in which orientation-dependent biases are less important) indicates that the ratio of Seyfert 2s to Seyfert 1s decreases significantly with infrared luminosity (e.g., Veilleux et al. 1995; Veilleux, Kim, & Sanders 1999a). The well-known decrease of the C IV $\lambda 1549$ equivalent widths with increasing luminosity (i.e. the UV Baldwin effect; e.g., Osmer & Shields 1999; Espey & Andreadis 1999) is another manifestation of this strong luminosity dependence. The Fe K$\alpha$ line and Compton scattering hump also are weaker in QSOs than in Seyferts (the X-ray Baldwin effect; e.g., Nandra et al. 1997). Finally, UV and X-ray narrow absorption lines are rarely seen in the spectra of quasars but not so in Seyferts (e.g., Turner et al. 1993; Mathur et al. 1999; Nicastro et al. 1999; Kaastra et al. 2000, 2002; Kaspi et al. 2002). All of these observations can be explained in the context of the unification model if the opening angle, or location of the inner edge, of the disk/torus/wind structure is allowed to vary with luminosity (e.g., Lawrence 1991; Hill et al. 1996; Elvis 2000).

3. New Constraints from Recent Surveys

The discussion in this section focusses on moderate-to-high luminosity AGNs. The reader should refer to reviews by Véron-Cetty & Véron 2000, Ho (2002), Barth (2002) and contributions in this Volume by Filippenko and Ho for discussions of recent results on low-luminosity AGNs (LLAGNs). Radio-loud AGNs are reviewed by Urry in this Volume so radio surveys are not discussed here.

3.1. UV/Optical: HES, 2dF, and SDSS

Several new surveys have improved our knowledge of AGN demography as a function of redshift; three of them are discussed here. The results from the Hamburg/ESO Bright QSO Survey (HES; e.g., Wisotzki et al. 2000) indicate that the local QSO density is $\sim 50\%$ larger than previously thought (e.g., Bright
Quasar Survey of Schmidt & Green 1983). The 2dF QSO Redshift Survey (e.g., Boyle et al. 2000) and the Sloan Digital Sky Survey (SDSS; e.g., Fan et al. 2001) have nicely confirmed that the QSO density rises steeply up to \( z \sim 2 \) and decreases beyond \( z \sim 3 \). At the time of writing, SDSS has revealed four quasars at \( z > 5.8 \). This set of high-\( z \) QSOs should at least double in size by the time the survey is completed. These objects will provide important new constraints on the epoch of QSO/galaxy formation (see, e.g., Haiman & Cen 2002).

### 3.2. Infrared: 2MASS

The Two Micron All Sky Survey (2MASS) has uncovered a large population of red (\( J - K > 2 \)) AGNs at relatively small redshifts (median \( z \sim 0.25 \); Cutri et al. 2001; see also Gregg et al. 2002). Approximately 75% of these sources are previously unidentified AGNs whose space density (\( \sim 0.5 \) deg\(^{-2} \)) is comparable to that of optical/UV selected AGNs of the same IR magnitudes. A large fraction (\( \sim 80\% \)) of these objects are Type 1 AGNs. Chandra follow-up observations of some of these AGNs indicate that all of them are X-ray faint, with the reddest being the faintest in X-rays (Wilkes et al. 2002). Interestingly, these broad-lined AGNs show significant absorption (several of them have \( N_H \sim 10^{22} \) cm\(^{-2} \)) and may be important contributors to the cosmic X-ray background (CXB; cf. §3.3; see also Webster et al. 1995; Benn et al. 1998; Whiting et al. 2001 for analyses of similar PKS radio-selected red QSOs).

### 3.3. X-Rays: BeppoSax, Chandra, and XMM-Newton

As mentioned in §2, X-ray observations generally provide support for the unification model of Seyfert galaxies. However, there are a number of important exceptions. These mismatches in the optical – hard X-ray classification fall into three broad categories: (1) Several broad-line AGNs show significant absorption in the X-rays (e.g., Seyferts and QSOs: Fiore et al. 2001, 2002, Wilkes et al. 2002; BALQSOs: Mathur et al. 2001, Gallagher et al. 2002). (2) Deep X-ray surveys have revealed a large population (\( \sim 40 - 60\% \)) of X-ray bright sources with no obvious optical AGNs (e.g., Barger et al. 2001, 2002; Tozzi et al. 2001; Stern et al. 2002b; Fiore et al. 2002). (3) A number of Seyfert 2 galaxies show no obvious X-ray absorption (e.g., Ptak et al. 1996; Bassani et al. 1999; Pappa et al. 2001; Panessa & Bassani 2002). The first category of objects may be explained in the context of the unification model if dust near the AGN is different from Galactic (e.g., different dust/gas ratio, metallicity, grain size; Veilleux et al. 1997a; Maiolino et al. 2001) or is not co-spatial with the (neutral and ionized) material producing the X-ray absorption (e.g., Veilleux et al. 1997a). X-ray bright sources with no obvious optical AGNs may be powered through inefficient ADAF-like accretion with \( L/L_{\text{Edd}} < 10^{-3} \), or perhaps the apparent lack of optical AGNs in these sources is simply due to strong dilution effects by the host galaxy light (e.g., Moran, Filippenko, & Chornock 2002). Finally, narrow-line AGNs with no obvious X-ray absorption have often been shown to be (nearly) Compton thick when observed in the hard X-rays. Half of all nearby optically selected Seyfert 2s may fall in this category [e.g., Risaliti et al. 1999; well-known examples include NGC 1068, NGC 4945 (Done, Madejski, & Smith 1996), and Circinus (Matt et al. 1999)]. Luminous examples also exist, although they may be less common: e.g., QSO-2s (Norman et al. 2002; Crawford et al. 2002).
The AGN Paradigm: Radio-Quiet Objects

2002; Stern et al. 2002a), X-ray detected Extremely Red Objects (EROs) with $R - K > 5$ (e.g., Alexander et al. 2002; Mainieri et al. 2002), and ultraluminous infrared galaxies (e.g., NGC 6240; Iwasawa & Comastri 1998; Vignati et al. 1999).

The improved sensitivity of the current X-ray facilities has allowed to search for possible evolutionary effects in the X-ray spectra of quasars and AGNs over a broad redshift range. Brandt et al. (2002) and Mathur, Wilkes, & Ghosh (2002) recently failed to find convincing evidence for a redshift dependence of the optical – X-ray slope in QSOs out to $z \sim 6$. Bechtold et al. (2002) come to a different conclusion using a larger comparison sample. A significant population of buried Type 2 AGNs with peak emissivity around $z \sim 0.8$ (rather than $z \sim 2 - 3$ for Type 1 AGNs; §3.1) appears to be needed to explain the properties of the CXB and the redshift dependence of the number density of X-ray sources in the deep Chandra and XMM surveys (e.g., Rosati et al. 2002; Franceschini, Braito, & Fadda 2002). These results may imply that Type 1 and 2 AGNs follow different evolutionary paths, in disagreement with the AGN unification model. Note, however, that the recent discovery of a large population of strongly absorbed Type 1 AGNs by Wilkes et al. (2002) may affect these conclusions.

4. Host Galaxy – SMBH – Starburst – AGN Connection

Ground-based and HST observations of the stellar and gas kinematics near the center of “normal” (inactive) galaxies have revealed a close connection between the mass of the supermassive black hole at the center of each of these objects and the mass of the spheroidal component (e.g., Kormendy & Richstone 1995; Faber et al. 1997; Magorrian et al. 1998; Gebhardt et al. 2000; Kormendy & Gebhardt 2001; Merritt & Ferrarese 2001; Tremaine et al. 2002) and perhaps also the mass of the dark matter halo (Ferrarese 2002). The results of reverberation mapping in AGNs suggest that the $M_{\text{BH}} - M_{\text{bulge}} - \sigma$ relations found in inactive galaxies also apply to active galaxies (e.g., Wandel, Peterson, & Malkan 1999; Kaspi et al. 2000; Peterson & Wandel 2000; Laor 2001; Onken & Peterson 2001; McLure & Dunlop 2002; Ferrarese et al. 2001; although see Krolik 2001). These results suggest a causal connection between spheroid/galaxy formation, black hole growth and AGN activity (e.g., Efstathiou & Rees 1988; Small & Blandford 1992; Haehnelt & Rees 1993; Chokshi 1997; Silk & Rees 1998; Haiman & Loeb 1998; Fabian 1999; Kauffmann & Haehnelt 2000; Burkert & Silk 2001; Adams, Graff, & Richstone 2001). This tight SMBH – host galaxy connection is discussed in more detail by Urry, Peterson, and Merritt in this Volume.

A strong connection also exists between starbursts and AGNs (Veilleux 2001; also Ward this Volume). Nuclear starbursts appear to be present in several Seyfert galaxies, based on the strength of UV and optical absorption and emission features from young/intermediate-age stars in the nuclear spectra of these objects (e.g., Terlevich, Diaz, & Terlevich 1990; Heckman et al. 1997; Gonzalez Delgado et al. 1998, 2001). The presence of extended soft thermal X-ray emission in Seyferts also supports this scenario (e.g., Levenson, Weaver, & Heckman 2001). Claims that starbursts are more common in Seyfert 2s than in Seyfert 1s have been made for many years (e.g., Rodriguez-Espinosa, Rudy, & Jones 1986; Pier & Krolik 1993; Maiolino et al. 1995; Nelson & Whittle
but orientation-dependent selection criteria may seriously bias some of these samples and cause the apparent Seyfert 1 / Seyfert 2 dichotomy.

The nuclear starbursts in active galaxies may have a very strong impact on the evolution of the host galaxy and the AGN itself. The stellar winds and supernovae associated with the nuclear starburst may deposit sufficient amounts of mechanical energy at the centers of these objects to severely disrupt the gas phase of these systems and result in large-scale galactic winds. A well-known example of starburst-driven wind in an active galaxy is NGC 3079. Detailed optical, radio, and X-ray studies of this object have revealed the presence of a powerful galactic wind that is strongly interacting with the ambient material of the host galaxy (e.g., Veilleux et al. 1994; Cecil et al. 2001; Cecil, Bland-Hawthorn, & Veilleux 2002). The wind event is clearly disturbing the distribution of gas within the central kpc of this object and may therefore also affect the feeding of the AGN. The frequency of starburst-driven winds in AGNs is poorly constrained (see Veilleux & Rupke 2002 for a discussion of a promising search technique), but if common these winds may provide negative feedback on the fueling mechanisms of AGNs (e.g., Rupke, Veilleux, & Sanders 2002).

5. Fueling and Triggering Mechanisms

The broad range in luminosity of AGN ($< 10^9 - 10^{14} \, L_\odot$) implies accretion rates of order $\lesssim 0.001 - 100 \, M_\odot \, yr^{-1}$ (assuming a radiative efficiency of 10% in rest mass units); the required accretion rates are very small for LLAGNs but quite substantial for QSOs. The requirements on the fueling/triggering processes for AGNs are therefore highly dependent on the AGN luminosity. Local processes are sufficient to power LLAGNs and Seyferts, but galactic-scale phenomena may be required to explain powerful QSOs. A broad range of processes including galaxy interactions and mergers, large-scale and nuclear bars, and nuclear gaseous spirals have been proposed to account for the fueling of Seyferts and LLAGNs (see Combes 2000 and the contribution by Combes in this Volume). The lack of obvious excess of companions and mergers seems to rule out the possibility that galaxy interactions and mergers are solely responsible for triggering these objects (e.g., Fuentes-Williams & Stocke 1988; Dultzin-Hacyan et al. 1999; De Robertis, Yee, & Hayhoe 1998; Virani, De Robertis, & VanDalfsen 2000). A slight (2.5-$\sigma$) excess of bars appear to be present among Seyferts (e.g., Knapen, Shlosman, & Peletier 2000; Laine et al. 2002; Knapen this Volume; although see Mulchaey & Regan 1997; Regan & Mulchaey 1999; Martini et al. 2001), but this result cannot explain Seyfert activity in galaxies without bars. Nuclear (0.1 – 1 kpc) gaseous spirals have been detected in most Seyferts but they also appear to be present in several normal galaxies and therefore cannot be the only reason for the Seyfert activity (e.g., Ford et al. 1994; Dopita et al. 1997; Laine et al. 1999, 2001; Martini & Pogge 1999; Regan & Mulchaey 1999; Pogge & Martini 2002; Emsellen this Volume). Most likely, these various processes help replenish a reservoir of fuel on scales of $\sim 100 \, pc$ or larger, but other processes are needed to carry the material down to sub-pc scales (e.g., gas instabilities, stellar ejecta, magnetic fields). Unfortunately, very little is known observationally on scales $\lesssim 10 \, pc$. 
The origin of the activity in high-luminosity objects is perhaps less ambiguous than in low-luminosity objects. Hosts of luminous QSOs generally appear to be elliptical galaxies (e.g., Dunlop et al. 2002; although see McLeod & McLeod 2001), but signs of interaction are seen in several QSOs, especially in those with infrared excess (e.g., Surace, Sanders, & Evans 2001; Canalizo & Stockton 2000, 2001). Several of these objects contain large quantities of molecular gas (e.g., Evans et al. 2001), suggestive of a gas-rich merger origin. Ultraluminous infrared galaxies (ULIGs) have long been suspected to be the progenitors of optical quasars based on the fact that nearly all ULIGs show signs of recent galaxy mergers and starburst/AGN activity, but only recently has there been a large enough homogeneous sample of ULIGs to look carefully at this question. Recent optical, near-infrared, and mid-infrared spectroscopic surveys of the 1-Jy sample of 118 ULIGs indicate that ∼30% (50%) of the objects with log[L_{IR}/L_{⊙}] ≥ 12.0 (12.3) are powered predominantly by a quasar rather than a starburst (e.g., Kim, Veilleux, & Sanders 1998; Genzel et al. 1998; Veilleux, Kim, & Veilleux 1999a; Lutz, Veilleux, & Genzel 1999). A recent morphological analysis of the 1-Jy sample indicates strong trends between infrared luminosity and colors, quasar activity, and merger phase (Veilleux, Kim, & Sanders 2002). All ULIGs in the 1-Jy sample are found to be in the pre-merger or final merger phase. About ∼70% of the extreme ULIGs with log[L_{IR}/L_{⊙}] > 12.5 are single-nucleus advanced mergers. All (most) Seyfert 1s (2s) in the sample are also advanced mergers. The R- and K′-band profiles in 73% of the single-nucleus advanced mergers are well fitted over R = 4 – 12 kpc by an elliptical-like R^{1/4} law (see also Scoville et al. 2000; Cui et al. 2001). These elliptical-like hosts follow the same R-band μ_e – r_e relation as normal ellipticals, suggesting that these objects may eventually become intermediate-luminosity (1 – 3 L*) elliptical galaxies if they get rid of their excess gas or transform the gas into stars. The hosts of ULIGs show a broad range in luminosity (mean ∼ 2 L*) which overlaps with that of QSO hosts. The R – K′ colors of ULIG hosts (mean ∼ 3.0) are also similar to those of QSO hosts and normal ellipticals. The average half-light radius of ULIGs is 4.8 ± 1.4 kpc at R and 3.5 ± 1.4 kpc at K′, similar to the QSO host sizes measured at H by McLeod & McLeod (2001) but slightly smaller than those measured at R by Dunlop et al. (2002). The reason for this apparent discrepancy between the two QSO datasets is not known. Overall, these results support the scenario in which the ULIG is the result of the merger of two ∼ L* disk galaxies which eventually evolves into an elliptical-like galaxy with a powerful AGN. There are obviously exceptions to this scenario and this is why a large sample of objects like the 1-Jy sample is needed to draw statistically meaningful conclusions.

6. Summary and Unanswered Questions

The following is a list of outstanding issues and unanswered questions:

1. There is strong general support for the AGN unification model (Fig. 1), but there are important exceptions: (a) not all Seyfert 2s show HBLRs. This may be a real effect or it could be due to instrument sensitivity (i.e. not enough “mirrors” to scatter the BLR emission back into our line of sight). (b) Optical and X-ray classifications are not always consistent with each other. These classification mismatches may be explained by non-
standard dust near AGNs, inefficient ADAF-like accretion, dilution effects by galaxy light, or Compton thickness.

2. The luminosity dependence of the Type 2 / Type 1 AGN ratio and the UV and X-ray Baldwin effects of the emission and absorption lines in AGNs require that the geometry of the disk/torus/wind structure depends on AGN luminosity. The exact dependence relies on knowing the fraction of obscured Type 2 AGNs, which is still subject to large uncertainties.

3. Recent Chandra investigations of high-redshift quasars come to conflicting conclusions regarding possible evolutionary effects of the sources of energy and absorption. The situation at low redshift is less ambiguous: The properties of the CXB and results from deep Chandra and XMM surveys appear to require a significant population of buried Type 2 AGNs with peak emissivity around $z \sim 0.8$, rather than $z \sim 2 - 3$ for unobscured Type 1 AGNs. These results may imply that Type 1 and 2 AGNs follow different evolutionary paths, in contradiction with the AGN unification model. The recent discovery of a large population of partially obscured Type 1 AGNs at low redshifts may affect these conclusions.

4. There is now strong evidence that the host galaxy – SMBH connection originally found in inactive galaxies also applies to active galaxies. Emission-line methods to test this connection at high redshifts are promising but will undoubtedly be less accurate (e.g., Nelson 2000; McLure & Jarvis 2002; Vestergaard 2002).

5. There appears to be a symbiotic relation between starbursts and AGNs. The origin of this relation is not known. The surveys suggesting a greater occurrence of (circumnuclear) starbursts in Seyfert 2s than in Seyfert 1s are often strongly affected by selection biases. Feedback from starburst-driven galactic winds may be one of many side effects of this tight starburst – AGN connection. This wind phenomenon is particularly important in understanding AGN activity at high redshift.

6. Minor mergers, bars, and nuclear spirals may all combine to bring the fuel down to $\sim 100$ pc in Seyferts and LLAGNs, but it is not clear what happens next. There is now strong evidence that gas-rich mergers are able to trigger some QSOs at low redshifts after undergoing a ULIG phase, but there is very few observational constraints on the formation process for the bulk of QSOs that were formed at $z \sim 2 - 4$.

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References

Adams, F. C., Graff, D. S., & Richstone, D. O. 2001, ApJ, 551, L31
The AGN Paradigm: Radio-Quiet Objects

Alexander, D. M. 2001, MNRAS, 320, L15
Alexander, D. M., et al. 2002, AJ, 123, 1149
Antonucci, R. 2001, in IAU Coll. 184, AGN Surveys, eds. R.F. Green, F.Ye. Khachikian, and D.B. Sanders, ASP Conf. Series, in press [astro-ph/0110343]
Antonucci, R. R. J., & Miller, J. S. 1985, ApJ, 297, 621
Barger, A. J., et al. 2001, AJ, 121, 662
—. 2002, AJ, 124, 1839
Barth, A. J. 2002, in Issues in Unification of Active Galactic Nuclei, ASP Conf. Series 258, eds. R. Maiolino, A. Marconi, and N. Nagar, 147
Bassani, L., et al. 1999, ApJS, 121, 473
Bechtold, J., et al. 2002, ApJ, in press [astro-ph/0204462]
Benn, C. R., et al. 1998, MNRAS, 295, 451
Boyle, B. J., et al. 2000, MNRAS, 317, 1014
Braatz, J. A., Wilson, A. S., & Henkel, C. 1997, ApJS, 110, 321
Brandt, W. N., et al. 2002, ApJ, 569, L5
Burkert, A., & Silk, J. 2001, ApJ, 554, L151
Canalizo, G., & Stockton, A. 2000, AJ, 120, 1750
—. 2001, ApJ, 555, 719
Cecil, G., Bland-Hawthorn, J., & Veilleux, S. 2002, ApJ, 576, 745
Cecil, G., et al. 2001, ApJ, 555, 338
Chokshi, A. 1997, ApJ, 491, 78
Clavel, J., et al. 2000, A&A, 357, 839
Combes, F. 2000, Lectures given at GH Advanced Lectures on the Starburst-AGN Connection, INAOE, eds. D. Kunth, I. Arexaga
Crawford, C. S., et al. 2002, MNRAS, 333, 809
Cui, J., et al. 2001, AJ, 122, 63
Cutri, R., et al. 2001, in New Era of Wide Field Astronomy, ASP Conf. Series 232, eds. R. Clowes, A. Adamson, and G. Bromage, 78
De Robertis, M. M., Yee, H. K., & Hayhoe, K. 1998, ApJ, 496, 93
Done, C., Madejski, G. M., & Smith, D. A. 1996, ApJ, 463, L63
Dopita, M. A., et al. 1997, ApJ, 490, 202
Dulzin-Hacyan, D., et al. 1999, in Galaxy Interactions at Low and High Redshift, IAU Symp. #186, 329
Dunlop, J. S., et al. 2002, MNRAS, in press [astro-ph/0108397]
Efstathiou, G., & Rees, M. J. 1988, MNRAS, 230, 5P
Elvis, M. 2000, ApJ, 545, 63
Espey, B., & Andreadis, S. 1999, in Quasars and Cosmology, ASP Conf. Series 162, Eds. G. Ferland and J. Baldwin, 351
Evans, A. S., et al. 2001, ApJ, 521, L107
Faber, S. M., et al. 1997, AJ, 114, 1771
Fabian, A. C. 1999, MNRAS, 309, 39
Fabian, A. C., et al. 2002, MNRAS, 335, L1
Fan, X., et al. 2001, AJ, 122, 2833
Ferrarese, L. 2002, ApJ, 578, 90
Ferrarese, L., et al. 2001, ApJ, 555, L79
Fiore, F., et al. 2001, MNRAS, 327, 771
Ford, H. C., et al. 1994, ApJ, 435, L27
Franceschini, A., Brato, V., & Fadda, D. 2002, MNRAS, 335, L51
Fuentes-Williams, F., & Stocke, J. T. 1988, AJ, 96, 1235
Gallagher, S. C., et al. 2002, ApJ, 567, 37
Gallimore, J. F., Baum, S. A., & O’Dea, C. P. 1997, Nature, 388, 852
Gallimore, J. F., et al. 2001, ApJ, 556, 694
Gebhardt, K., et al. 2000, ApJ, 539, L13
Genzel, R., et al. 1998, ApJ, 498, 579
Gonzalez Delgado, R. M., et al. 1998, ApJ, 505, 174
Gonzalez Delgado, R. M., Heckman, T., & Leitherer, C. 2001, ApJ, 546, 845
Greenhill, L. J., et al. 1996, ApJ, 472, L21
Greenhill, L. J., & Gwinn, C. R. 1997, Ap&SS, 248, 261
Greenhill, L. J., Moran, J. M., & Herrnstein, J. R. 1997, ApJ, 481, L23
Gregg, M. D., et al. 2002, ApJ, 564, 133
Gu, Q., Dultzin-Hacyan, D., & de Diego, J. A. 2001, RMxAA, 37, 3
Gu, Q., & Huang, J. 2002, ApJ, 579, 205
Guainazzi, M., et al. 1999, A&A, 341, L27
Haehnelt, M. G., & Rees, M. J. 1993, MNRAS, 263, 168
Haiman, Z., & Cen, R. 2002, ApJ, 578, 702
Haiman, Z., & Loeb, A. 1998, ApJ, 503, 505
Haniff, C. A., Wilson, A. S., & Ward, M. J. 1988, ApJ, 334, 104
Heckman, T. M., et al. 1997, ApJ, 482, 114
Heisler, C. A., Lumsden, S. L., & Bailey, J. A. 1997, Nature, 385, 700
Hill, G. J., Goodrich, R. W., & DePoy, D. L. 1996, ApJ, 462, 163
Ho, L. C. 2002, in AGN Surveys, Proceedings of IAU Coll. 184, eds. R. F. Green, E. Y. Khachikian, and D. B. Sanders, in press
Iwasawa, K., & Comastri, A. 1998, MNRAS, 297, 1219
Iwasawa, K., et al. 1996, MNRAS, 282, 1038
Iwasawa, K., et al. 1999, MNRAS, 306, L19
Kaastra, J. S., et al. 2000, A&A, 354, L83
—–. 2002, A&A, 386, 427
Kaspi, S., et al. 2000, ApJ, 533, 631
—–. 2002, ApJ, 574, 643
Kauffmann, G., & Haehnelt, M. 2000, MNRAS, 311, 576
Kay, L. E. 1994, ApJ, 430, 196
Kim, D.-C., Veilleux, S., & Sanders, D. B. 1998, ApJ, 508, 627
—–. 2002, ApJS, 143, 000 [astro-ph/0207373]
Kinkhabwala, A., et al. 2002, ApJ, 575, 732
Knapen, J. H., Shlosman, I., & Peletier, R. F. 2000, ApJ, 529, 93
Kormendy, J., & Gebhardt, K. 2001, in The 20th Texas Symposium on Relativistic Astrophysics, AIP Conf. Proc. #586, eds. H. Martel and J. C. Wheeler, 363
Kormendy, J., & Richstone, D. 1995, ARAA, 33, 581
Krolik, J. H. 2001, ApJ, 551, 72
Laine, S., et al. 1999, ApJ, 511, 709
The AGN Paradigm: Radio-Quiet Objects

Laor, A. 2001, ApJ, 567, 97
Lawrence, A. 1991, MNRAS, 252, 586
Lee, J. C., et al. 2002, ApJ, 570, L47
Levenson, N. A., Weaver, K. A., & Heckman, T. M. 2001, ApJ, 550, 230
Lumsden, S., et al. 2001, MNRAS, 327, 459
Lutz, D., Veilleux, S., & Genzel, R. 1999, ApJ, 517, L13
Lutz, D., et al. 2002, A&A, in press (astro-ph/0209477)
Magorrian, J., et al. 1998, AJ, 115, 2285
Maiolino, R., et al. 1995, ApJ, 446, 561
—. 1998, A&A, 338, 781
—. 2001, A&A, 365, 37
Mainieri, V., et al. 2002, A&A, 393, 425
Martini, P., & Pogge, R. W. 1999, AJ, 118, 2646
Martini, P., et al. 2001, ApJ, 562, 139
Mathur, S., Elvis, M., & Wilkes, B. J. 1999, ApJ, 519, 605
Mathurs, S, Wilkes, B. J., & Ghosh, H. 2002, ApJ, 570, L5
Mathur, S., et al. 2001, ApJ, 551, L13
Matt, G., et al. 1999, A&A, 341, L39
McLeod, K. K., & McLeod, B. A. 2001, ApJ, 546, 782
McLure, R. J., & Dunlop, J. S. 2002, MNRAS, 331, 795
McLure, R. J., & Jarvis, M. J. 2002, MNRAS, in press (astro-ph/0204473)
Merritt, D., & Ferrarese, L. 2001, ApJ, 547, 140
Miller, J. S., & Goodrich, R. W. 1990, ApJ, 355, 456
Miller, J. S., Goodrich, R. W., & Matthews, W. G. 1991, ApJ, 378, 47
Miyoshi, M., et al. 1995, Nature, 373, 127
Moran, E. C., Filippenko, A. V., & Chornock, R. 2002, ApJ, 579, L71
Moran, E. C., et al. 2000, ApJ, 540, L73
Mulchaey, J. S., & Regan, M. W. 1997, ApJ, 482, L135
Mulchaey, J. S., Wilson, A. S., & Tsvetanov, Z. 1996a, ApJS, 102, 309
—. 1996b, ApJ, 467, 197
Nandra, K., et al. 1997, ApJ, 488, L91
Nelson, C. H. 2000, ApJ, 544, L91
Nelson, C. H., & Whittle, M. 1996, ApJ, 465, 96
Nicastro, F., et al. 1999, ApJ, 512, 184
Norman, C. L., et al. 2002, ApJ, 571, 218
Onkel, C. A., & Peterson, B. M. 2002, ApJ, 572, 746
Osmer, P. S., & Shields, J. C. 1999, in Quasars and Cosmology, ASP Conf. Ser. 163, Eds. G. Ferland and J. Baldwin, 235
Panessa, F., & Bassani, L. A&A, in press (astro-ph/0208496)
Pappa, A., et al. 2001, MNRAS, 326, 995
Peterson, B. M., & Wandel, A. 2000, ApJ, 540, L13
Pier, E. A., & Krolik, J. H. 1993, ApJ, 418, 673
Pogge, R. W. 1989, ApJ, 345, 730
Pogge, R. W., & Martini, P. 2002, ApJ, 569, 624
Pogge, R. W., et al. 2000, ApJ, 532, 323
Ptak, A., et al. 1996, ApJ, 459, 542
Regan, M. W., & Mulchaey, J. S. 1999, AJ, 117, 2676
Risaliti, G., Maiolino, R., & Salvati, M. 1999, ApJ, 522, 157
Rodriguez-Espinosa, J. M., Rudy, R. J., & Jones, B. 1986, ApJ, 309, 76
Rosati, P., et al. 2002, ApJ, 566, 667
Rupke, D. S., Veilleux, S., & Sanders, D. B. 2002, ApJ, 570, 588
Schmidt, M., & Green, R. F. 1983, ApJ, 269, 352
Scoville, N. Z., et al. 2000, AJ, 119, 991
Silk, J., & Rees, M. J. 1998, A&A, 331, L1
Small, T. A., & Blandford, R. D. 1992, MNRAS, 259, 725
Stern, D., et al. 2002a, ApJ, 568, 71
Stern, D., et al. 2002b, AJ, 123, 2223
Surace, J. A., Sanders, D. B., & Evans, A. S. 2001, AJ, 122, 2791
Tadhunter, C., & Tsvetanov, Z. 1989, Nature, 341, 422
Tanaka, Y., et al. 1995, Nature, 375, 659
Terlevich, E., Díaz, A. I., & Terlevich, R. 1990, MNRAS, 242, 271
Tozzi, P., et al. 2001, ApJ, 562, 42
Tran, H. D. 2001, ApJ, 554, L19
Tremaine, S., et al. 2002, ApJ, 574, 740
Turner, T. J., et al. 1993, ApJ, 419, 123
——. 2002, ApJ, 574, L123
Urry, C. M., & Padovani, P. 1995, PASP, 107, 803
Veilleux, S. 2001, in Starburst Galaxies: Near and Far, Eds. L. Tacconi and D. Lutz.
Heidelberg: Springer-Verlag, 2001, p.88
——. 2002, in Extragalactic Gas at Low Redshift, eds. J.S. Mulchaey and J.T. Stocke,
ASP Conf. Series 254, 313
Veilleux, S., Kim, D.-C., & Sanders, D. B. 1999a, ApJ, 522, 113
——. 2002, ApJS, 143, 000 (astro-ph/0207401)
Veilleux, S., Goodrich, R. W., & Hill, G. J. 1997a, ApJ, 477, 631
Veilleux, S., & Rupke, D. S. 2002, ApJ, 565, L63
Veilleux, S., Sanders, D. B., & Kim, D.-C. 1997b, ApJ, 484, 92
Veilleux, S., Sanders, D. B., & Kim, D.-C. 1999b, ApJ, 522, 139
Veilleux, S., et al. 1994, ApJ, 433, 48
——. 1995, ApJS, 98, 171
Véron-Cetty, M. P., & Véron, P. 2000, A&A Rev., 10, 81
Vestergaard, M. 2002, ApJ, 571, 733
Vignati, P., et al. 1999, A&A, 349, L57
Virani, S. N., De Robertis, M. M., & VanDalsen 2000, AJ, 120, 1739
Wandel, A., Peterson, B. M., & Malkan, M. A. 1999, ApJ, 526, 579
Webster, R., et al. 1995, Nature, 375, 469
Whiting, M. T., Webster, R. L., & Francis, P. J. 2001, MNRAS, 323, 718
Wilkes, B. J., et al. 2002, ApJ, 564, L65
Wilms, J., et al. 2001, MNRAS, 328, L27
Wilson, A. S., & Tsvetanov, Z. 1994, AJ, 107, 1227
Wisotzki, L., et al. 2000, A&A, 358, 77
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