January 30, 2010

Dr. Richard Mushotzky, Professor
University of Maryland
Department of Astronomy
CSS 1204
College Park, MD 20742-2421
U.S.A.

Dear Prof. Mushotzky:

Please accept the attached application for your postdoctoral position to work within the High-Energy Extragalactic Astronomy group at the University of Maryland. I feel the post-doctoral position under your advisory is an excellent fit for me, and your research goals will benefit from my addition. My expertise in X-ray and radio astronomy ideally suits me for the advertised projects, and my familiarity with infrared, optical, and UV data analysis situates me to be successful within your research team.

My research program is devoted to developing a better understanding of galaxy clusters and AGN, and your recent publications suggest we have very similar scientific interests. I have been especially intrigued by your work involving Swift/BAT and would like the opportunity to contribute to that work. Additionally, as you state in the ad, I think utilization of high S/N and high resolution X-ray data, in conjunction with the vast wealth of archived UV data, is primed to expand our knowledge of the connection between AGN, star formation, and their host X-ray halos. The prospect of working with the UMD staff is very exciting as my research interests (observational and computational) overlap with many people currently there: K. Arnaud, T. Bogdanovic, M. Loewenstein, C. Markwardt, C. Reynolds, to name just a few.

Along with this letter are my CV, a list of publications, and a statement of research interests. Letters of recommendation from Megan Donahue, Mark Voit, and Brian McNamara should arrive under separate cover. Please do not hesitate to contact me if there is any further information I can provide as you review my application.

Thank you for your consideration.

Sincerely,

Dr. Kenneth W. Cavagnolo
University of Waterloo

Dr. Kenneth W. Cavagnolo
Curriculum Vitae

Last updated January 30, 2010; *Hyperlinks colored blue*

University of Waterloo   517-285-9062
Department of Physics & Astronomy   519-888-4567 ext. 35074
200 University Avenue West   kencavagnolo@gmail.com
Waterloo, Ontario, Canada N2L 3G1   www.pa.msu.edu/people/cavagnolo/

Education	Michigan State University Ph.D., Astronomy & Astrophysics	2005 - 2008
	Michigan State University M.S., Astronomy & Astrophysics, *magna cum laude*	2002 - 2005
	Georgia Institute of Technology B.S., Physics, *magna cum laude*	1998 - 2002
Research Experience	Postdoctoral Fellow Supervisor: Brian McNamara, *Univ. of Waterloo*	2008 - Present
	Graduate Research Assistant Supervisor: Megan Donahue, *Mich. St. Univ.*	2003 - 2008
	Graduate Research Assistant Supervisor: Jack Baldwin, *Mich. St. Univ.*	2002 - 2003
	Undergraduate Research Assistant Supervisor: James Sowell, *Geor. Inst. of Tech.*	2000 - 2002

Research Program & Interests

My research program is focused on better understanding the connection between AGN and their host environments, with a specific interest in the role of AGN feedback on the formation and evolution of galaxies, galaxy groups, and galaxy clusters.

Areas of interest:
- Mechanical and radiative AGN feedback
- Cosmic magnetic fields
- Conditions for quasar-mode vs. radio-mode dominance
- Black hole accretion mechanisms
- Thermalization of AGN feedback energy
- Formation of ICM thermal instabilities
- Galaxy cluster radio halos
- Cosmological studies via structure formation

Honors
- Referee for ApJ, ApJL, AJ, and CanTAC — 2008 - Present
- Sherwood K. Haynes Award for Outstanding Graduate Student — 2008

• MSU College of Natural Science Dissertation Fellow — 2007 - 2008
• ΣΞ National Scientific Research Society Member — 2009 - Present
• ΣΠΣ National Physics Honor Society Member — 2001 - Present
• American Astronomical Society Member — 2002 - Present
• American Physical Society Member — 2002 - Present
• Perimeter Institute Black Hole Reading Group Member — 2009 - Present
• Dean's List, Georgia Inst. of Tech. — 1998-2002

Scientific Skills

• Extensive experience with X-ray and radio data analysis
• Familiarity with infrared, optical, and UV data analysis
• Understanding of AIPS, CASA, CIAO, IRAF, OSA, and SAS analysis software
• Fluent in HTML, IDL, LaTeX, and PERL programming languages
• Working knowledge of C, FORTRAN, MySql, PYTHON, SuperMongo, and Tcl
• Mastery of DOS, Linux, Macintosh, and Windows computing architectures
• Expert of computer maintenance, system construction, and troubleshooting

Observing Experience

Giant Metrewave Radio Telescope (GMRT) — Jan. 2010
60 hours observing 15 galaxy clusters

Chandra X-ray Observatory (CXO) — Jan. 2009
21 hour queued observation of IRAS 09104+4109

Very Large Array Radio Telescope (VLA) — Dec. 2008
39 hours observing 13 giant ellipticals

Accepted Proposals & Grants

GMRT Cycle 17, Co-I — 2009
The Power and Particle Content of Extragalactic Radio Sources
PI: Somak Raychaudhury, *Univ. Birmingham*

GMRT Cycle 17, Co-I — 2009
The Morphology of Steepest Spectrum Radio Sources in Galaxy Cluster Cores
PI: Alastair Edge, *Durham Univ.*

NOAO Cycle 2008A & 2009A/B, Co-I — 2008-2009
Normalization and scatter of the $M - T$ relation for supermassive galaxy clusters
PI: Rachel Mandelbaum, *Princeton Univ.*

GMRT Cycle 16, Co-I — 2008
The Content of Giant Cavities in the IGM of Galaxy Clusters
PI: Somak Raychaudhury, *Univ. Birmingham*

CXO Cycle 10, PI — 2008
IRAS 09104+4109: An Extreme Brightest Cluster Galaxy

CXO Cycle 10, Co-I — 2008
Conduction and Multiphase Structure in the ICM
PI: Mark Voit, *Mich. St. Univ.*

	Spitzer Cycle 5, Co-I Star Formation and AGN Feedback in BCGs PI: Megan Donahue, *Mich. St. Univ.*	2008
	Spitzer Cycle 5, Co-I Infrared Properties of a Control Sample of Brightest Cluster Galaxies PI: Megan Donahue, *Mich. St. Univ.*	2008
	NSF Grant, Co-I Star Formation in the Universe's Largest Galaxies PI: Mark Voit, *Mich. St. Univ.*	2008
	CXO Cycle 9, Co-I Quantifying Cluster Temperature Substructure PI: Mark Voit, *Mich. St. Univ.*	2007
	VLA A-configuration Cycle, Co-I Radio Feedback in Clusters and Galaxies PI: Brian McNamara, *Univ. Waterloo*	2007
Students Advised	Clif Kirkpatrick, Ph.D. candidate, *Univ. Waterloo* The 2-Dimensional metal abundance distributions in galaxy clusters	2008-present
	Mina Rohanizadegan, M.Sc. candidate, *Univ. Waterloo* Constraining the spin of SMBHs using measured AGN jet powers	2008-present
	Brad Whuiska, Undergraduate research, *Univ. Waterloo* Finding the largest galactic cores in the HST archive	2009-present
	Rob Myers, Undergraduate research, *Univ. Waterloo* In search of radio galaxies via X-ray and radio catalog cross-correlation	2009-present
Teaching Experience	Substitute Instructor Course: "Visions of the Universe"	Fall 2006
	Honors Physics Tutor Course: "Introductory Honors Physics I & II"	Summer 2003
	Graduate Teaching Assistant Course: "Visions of the Universe"	2002 - 2003
References	Megan Donahue, donahue@pa.msu.edu Tenured professor, Michigan State University	+00-1-517-884-5618
	Brian McNamara, mcnamara@uwaterloo.ca Tenured professor, University of Waterloo	+00-1-519-888-4567 ext. 38170
	G. Mark Voit, voit@pa.msu.edu Tenured professor, Michigan State University	+00-1-517-884-5619

Chris Carilli, ccarilli@nrao.edu   +00-1-505-835-7000
National Radio Astronomy Observatory Chief Scientist

Jack Baldwin, baldwin@pa.msu.edu   +00-1-517-884-5611
Associate Chair for Astronomy, Michigan State University

Paul Nulsen, pnulsen@cfa.harvard.edu   +00-1-617-495-7043
Research Scientist, Center for Astrophysics at Harvard University

Mike Wise, wise@science.uva.nl   +31-0-521-595-564
LOFAR Radio Observatory Chief Scientist

Personal Interests

- Academic: Environmental sciences, "Cradle2Cradle" design, and urban planning.
- Athletics: Triathlons, running, baseball, and Georgia Tech athletics.
- Hobbies: Backpacking, reading, building model airplanes, and raising bonsai trees.

Dr. Kenneth W. Cavagnolo
List of Publications

Last updated January 30, 2010;

In Preparation

"A Relationship Between AGN Jet Power and Radio Luminosity"
K. Cavagnolo, B. McNamara, P. Nulsen, C. Carilli, C. Jones, W. Forman, & L. Bîrzan
Submitted to ApJ

"Mechanical Feedback from the Obscured Quasar in IRAS 09104+4109"
K. Cavagnolo, M. Donahue, B. McNamara, G. M. Voit, & M. Sun
Submitted to MNRAS

"A Multiwavelength Analysis of the Galaxy Cluster RBS 797: Evidence for a Cluster-scale Line-of-Sight AGN Outburst"
K. Cavagnolo, B. McNamara, P. Nulsen, M. Wise, M. Gitti, & M. Brüggen
In prep. for ApJ

"Entropy Scaling Relations of ACCEPT Galaxy Clusters"
K. Cavagnolo, G. M. Voit, M. Donahue, & S. Bruch
In prep. for ApJL

"The Complications of SMBH Spin Axis Reorientation and Implications for AGN Feedback Models"
K. Cavagnolo, B. McNamara, & N. Afshordi
In prep. for ApJL

"Normalization and Scatter of the Mass-Temperature relation for Supermassive Galaxy Clusters"
R. Mandelbaum, R. Nakajima, G. Bernstein, **K. Cavagnolo**, M. Donahue, C. Keeton, J. Hughes, N. Bahcall, T. Schrabback, N. Padmanabhan, S. Miyazaki, & A. Kravtsov
In prep. for ApJ

"Constraining the Spin of Supermassive Black Holes Using Measured AGN Jet Powers"
M. Rohanizadegan, B. McNamara, F. Kazemzadeh, P. Nulsen, & **K. Cavagnolo**
In prep. for ApJ

"Identifying AGN Feedback Relics Via Steep Spectrum Radio Sources"
A. Edge, **K. Cavagnolo**, H. Röttgering, B. McNamara, M. Wise, M. Brüggen, R. van Weeren, G. Brunetti, & J. Croston
In prep. for MNRAS

First Author Refereed Papers

"Intracluster Medium Entropy Profiles for a Chandra Archival Sample Of Galaxy Clusters"
K. Cavagnolo, M. Donahue, G. M. Voit, & M. Sun
ApJ Accepted, 2009

"An Entropy Threshold for Strong Hα and Radio Emission in the Cores of Galaxy Clusters"
K. Cavagnolo, M. Donahue, G. M. Voit, & M. Sun
ApJ Accepted, 2008

"Bandpass Dependence of X-Ray Temperatures in Galaxy Clusters"
K. Cavagnolo, M. Donahue, G. M. Voit, & M. Sun
ApJ Accepted, 2008

Co-Author Refereed Papers

"Direct Evidence for an Outflow of Metal-Enriched Gas Along the Radio Jets of Hydra A"
C. Kirkpatrick, M. Gitti, **K. Cavagnolo**, B. McNamara, L. David, P. Nulsen, & M. Wise
ApJL Accepted, 2009

"A Chandra X-ray Analysis of Abell 1664: Cooling, Feedback and Star Formation in the Central Cluster Galaxy"
C. Kirkpatrick, B. McNamara, D. Rafferty, P. Nulsen, L. Birzan, F. Kazemzadeh, M. Wise, M. Gitti, & **K. Cavagnolo**
ApJ Accepted, 2009

"Conduction and the Star Formation Threshold in Brightest Cluster Galaxies"
G. M. Voit, **K. Cavagnolo**, M. Donahue, D. Rafferty, B. McNamara, & P. Nulsen
ApJ Accepted, 2008

"Star Formation, Radio Sources, Cooling X-Ray Gas and Galaxy Interactions in the Brightest Cluster Galaxy in 2A0335+096"
M. Donahue, M. Sun, C. O'Dea, G. M. Voit, & **K. Cavagnolo**
AJ Accepted, 2007

"s-Process Abundances in Planetary Nebulae"
B. Sharpee, Y. Zhang, R. Williams, E. Pellegrini, **K. Cavagnolo**, J. Baldwin, M. Phillips, & X. Liu
ApJ Accepted, 2007

"Entropy Profiles in the Cores of Cooling Flow Clusters of Galaxies"
M. Donahue, D. Horner, **K. Cavagnolo**, & G. M. Voit
ApJ Accepted, 2006

Presented Work & Talks

POSTER: *"IRAS 09104+4109: At the Cross-roads of Massive Galaxy Formation?"*
Jun. 2010 – From Massive Galaxy Formation to Dark Energy; University of Tokyo-Kashiwa

POSTER: *"Probing SMBH Accretion History Via Radio Luminosities"*
Apr. 2010 – What drives the growth of black holes?; Durham University

TALK: *"The AGN Jet Power and Radio Power Relationship for Isolated Giant Elliptical Galaxies"*
Jun. 2009 – The Monster's Fiery Breath: Feedback in galaxies, groups, and clusters; University of Wisconsin-Madison

INVITED TALK: *"Using Galaxy Clusters as Galaxy Formation Labs"*
Oct. 2008 – Undergraduate Seminar Series; University of Waterloo

INVITED TALK: *"Understanding Cluster Cores: The Role of Core Entropy"*
Sep. 2008 – The Cool, Cooler and Cold - Cluster Cooling Flows in a New Light; Leiden University

INVITED TALK: *"Investigating Feedback and Relaxation in Clusters of Galaxies"*
Jul. 2008 – Center for Study of Cosmic Evolution; Michigan State University

INVITED TALK: *"From Cluster Cosmology to Galaxy Formation in Under One Hour"*
Mar. 2008 – Astrophysics Seminar; University of Waterloo

INVITED TALK: *"The Effect of Cluster Feedback on High-Precision Cosmology"*
Feb. 2008 – NASA Space Science and Technology Center; University of Alabama-Huntsville

INVITED TALK: *"Understanding Feedback in Galaxy Clusters"*
Jan. 2008 – Center for Study of Cosmic Evolution; Michigan State University

INVITED TALK: *"Band Dependence of X-ray Temperatures"*
Oct. 2007 – Astrophysics Seminar; University of Michigan

POSTER: *"The Entropy-Feedback Connection and Quantifying Cluster Virialization"*
Oct. 2007 – Eight Years of Science with Chandra; University of Alabama-Huntsville

POSTER: *"Chandra Studies of Dark Matter and Galaxy Formation: Signatures from the Intracluster Medium"*
Dec. 2006 – American Astronomical Society Meeting

PROCEEDING: *"Abundances of s-process elements in planetary nebulae: Br, Kr & Xe"*
Jul. 2006 – International Astronomical Union Symposium

POSTER: *"Studies of Entropy Distributions in X-ray Luminous Clusters of Galaxies"*
Dec. 2005 – American Astronomical Society Meeting

POSTER: *"Entropy Distributions in the Cores of Nearby X-ray Luminous Clusters of Galaxies"*
Dec. 2004 – American Astronomical Society Meeting

POSTER: *"Radio-Free Cluster Cooling Flows"*
Dec. 2004 – American Astronomical Society Meeting

Dr. Kenneth W. Cavagnolo
Statement of Research Interests

Introduction

The energy liberated by active galactic nuclei (AGN) plays a vital role in regulating the process of hierarchical structure formation [*e.g.* 1, 2, 3, 4, 5, 6]. Observations robustly indicate most, if not all, galaxies harbor a centralized SMBH which has co-evolved with the host galaxy giving rise to the well-known bulge luminosity-stellar velocity dispersion correlation [7, 8]. The current galaxy formation paradigm couples the processes of environmental cooling and heating via feedback loops [9, 10]. In broad terms, feedback has been segregated into two modes which occur at different cosmic epochs: an early-time radiatively-dominated quasar mode, and a late-time mechanically-dominated AGN mode. While this model is successful in reproducing the bulk properties of the Universe, the details (*i.e.* accretion processes, obscuration, power generation, energy dissipation) are poorly understood. It is these details which interest me most.

Relevant Completed and On-going Research

My research has focused primarily on understanding the mechanical feedback from AGN and the associated effects on galaxy clusters. I have devoted particular attention to intracluster medium (ICM) entropy distribution [11], the process of cluster virialization [12], the mechanisms by which SMBHs might accrete fuel from an environment [13], and how those mechanisms correlate with properties of clusters cores [14].

From these studies it has become apparent that certain conditions must be established within a cluster core (and presumably any environment which supplies fuel for a SMBH, *e.g.* cool coronae [15]), namely that the mean entropy (K) of the large-scale environment hosting a SMBH must be $K \lesssim 30$ keV cm^2. Coincidentally, this is the entropy scale above which thermal electron conduction is capable of stabilizing a cluster core against the formation of thermal instabilities, hinting at a method for coupling AGN feedback energy to the ICM and establishing a self-regulating feedback loop. This result is made more interesting if the heat-flux-driven-buoyancy instability [HBI, 16] is an important process in clusters with central cooling times $\ll H_0^{-1}$. Full MHD simulations have shown that the HBI, in conjunction with reasonable magnetic field strengths ($\sim 1~\mu$G), modest heating from an AGN ($\sim 10^{43}$ erg s^{-1}) and subsonic turbulence, can feasibly stabilize a core against catastrophic cooling [17, 18]. In addition, recent radio polarization measurements for Virgo cluster galaxies suggest the large-scale magnetic field of Virgo's ICM is radial oriented [19]. This result is tantalizing since it suggests the magnetothermal instability [20] may be operating within Virgo, furthering the case that conduction is a vital component of understanding galaxy cluster evolution. In total, these studies touch on a larger subject which is of great interest to me: magnetic fields in clusters.

LOFAR came online fall 2009, and the order of magnitude improvement in angular resolution and sensitivity at low radio frequencies opens a new era in studying ICM magnetic fields via polarimetry [21]. Polarization measurements made with LOFAR will enable direct detection of ICM field strengths and structure on scales as small as cluster cores ($\lesssim 50$ kpc) and as large as cluster virial radii ($\sim$ few Mpc). A

systematic study of a cluster sample using LOFAR will expand our view of magnetic field demographics and how they relate to cluster properties like temperature gradients, core entropy, recent AGN activity, and the structure of cold gas filaments in cluster cores. In addition, we will be able to investigate the origin and evolution of the fields: were they seeded by early AGN activity? Are they amplified by mergers? Is there evidence of draping or entrainment? Understanding cluster magnetic fields will also place constraints on ICM properties, like viscosity, which govern the microphysics by which AGN feedback energy might be dissipated as heat, *e.g.* via turbulence and/or MHD waves.

My most recent research has focused on the SMBH engines which underlie AGN. One study recently completed [22] investigates a more precise calibration between AGN jet power ($P_{\rm jet}$) and emergent radio emission ($L_{\rm radio}$) for a sample of giant ellipticals (gEs) and BCGs. In this study we estimated $P_{\rm jet}$ using cavities excavated in the ICM as bolometers, and measured $L_{\rm radio}$ at multiple frequencies using new and archival VLA observations. We found, regardless of observing frequency, that $P_{\rm jet} \propto 10^{16} L_{\rm radio}^{0.7}\,{\rm erg~s}^{-1}$, which is in general agreement with models for confined heavy jets. The utility of this relation lies in being able to estimate total jet power from monochromatic all-sky radio surveys for large samples of AGN at various stages of their outburst cycles. This should yield constraints on the kinetic heating of the Universe over swathes of cosmic time, and as a consequence, can be used to infer the total accretion history and growth of SMBHs over those same epochs.

An interesting result which has emerged from our work, and which is investigated in [23], is that FR-I radio galaxies (classified on morphology and not $L_{\rm radio}$) appear to be systematically more radiatively efficient than FR-II sources. This may mean there are intrinsic differences in radio sources (light and heavy jets), or possibly that all jets are born light and become heavy on large scales due to entrainment. One way to investigate this result more deeply is to undertake a systematic study of the environments hosting radio galaxies utilizing archival *Chandra* and VLA data.

With tighter observational constraints on the kinetic properties of AGN jets, of interest to me is re-visiting existing models for relativistic jets in an ambient medium. Utilizing observationally-based estimates of jet power, it is possible to better understand the growth of a radio source including effects like entrainment and evolution of jet composition [á la 24]. Another interesting use of a universal $P_{\rm jet}$-$L_{\rm radio}$ relation is using radio luminosities, lobe morphologies, and age estimates to predict ambient gas pressures: $p_{\rm amb} \propto (t_{\rm age} L_{\rm radio})/V_{\rm radio}$. This yields an estimate of ambient densities when basic assumptions are made about environment temperatures: $\rho_{\rm amb} \propto p/T$. With an estimate of ambient densities, X-ray observing plans for very interesting radio sources which reside in faint group environments (*i.e.* FR-I sources) can be robustly prepared. An observationally-based estimate of $P_{\rm jet}$ also enables the investigation of relations between observable mass accretion surrogates (*i.e.* Hα luminosity, molecular/dust mass, or nuclear X-ray luminosity) and AGN energetics for the purpose of establishing clearer connections with accretion mechanisms and efficiencies.

Future Research

The study of mechanically-dominated AGN feedback has advanced quickly in the last decade primarily because the process is readily observed at low-redshifts, and the hot gas phase which this mode of feedback most efficiently interacts is accessible with the current generation of X-ray observatories. However, the frequency of AGN feedback as a function of environment and our understanding of radiative feed-

back has not progressed as quickly. The former results from the limitations of existing X-ray samples, while the latter is a consequence of obscuration which prevents direct observational study [25]. Luckily, the quality and availability of multi-frequency data (radio, sub-mm, IR, optical, UV, and hard X-ray) needed to probe AGN duty cycles and obscuration is poised to improve with new facilities and instruments coming on-line (*i.e.* LOFAR, Herschel, SCUBA-2, SOFIA, ALMA, NuStar, Simbol-X). As such, there are a number of questions regarding the formation and evolution of SMBHs that I would like to pursue.

What is the evolutionary track from young, gas-rich, dusty galaxies to present-day old, parched gEs? It has been argued that high-z sub-mm galaxies (SMGs) are the progenitors for low-z Magorrian spirals and ellipticals, suggesting SMGs are useful for studying the co-evolution of SMBHs and host galaxies. It has been shown SMGs are found in very dense environments and have high AGN fractions ($\gtrsim 50\%$) [26], so they are excellent for identifying the rapidly cooling high-z gas-rich regions where star formation and AGN activity can be fueled. Hence, SMGs identify a population primed for follow-up with far-IR, UV, and X-ray spectroscopy to study feedback and cooling in unique environments. In total, SMGs may be the missing piece to understanding how SMBH evolution and AGN activity regulate the transition from gas-rich progenitors to "red and dead" ellipticals. It has also been posited that SMGs are high-z analogs of low-z ULIRGs (objects typically associated with the sites of merging gas-rich spirals). If this is the case, insight to ULIRG evolution can be gained from studying SMGs. ULIRGs are an interesting population on their own, one for which limited X-ray spectroscopic studies have been undertaken. We know these systems to, on average, be dominated by star formation, however, some systems may have significant contribution from AGN, and these systems can be used to further understand the nature of evolving gas-rich systems.

How does AGN activity depend on environment? Specifically what is the relationship between redshift, environment, duty cycle, and feedback energy? For a variety of reasons, the answer thus far is unclear. The lack of comprehensive X-ray samples, particularly for low X-ray luminosities (*i.e.* sub-Eddington accretors), has been a specific hindrance. To this end, a study of the faint radio galaxy population using archival *Chandra* and VLA data, possibly for a sample of hard X-ray selected sources, would be interesting. Undertaking a systematic study of radio galaxy properties (*i.e.* jet composition, morphologies, outflow velocities, magnetic field configurations) as a function of environment (*i.e.* ambient pressure, halo compactness) can help address how AGN energetics couple to environment, which ultimately suggests how accretion onto the SMBH couples to environment on small and large scales. Deep *Chandra* observations for a sample of FR-I's (a poorly studied population in the X-ray) would also be useful for addressing the AGN-environment connection, and the P_{jet}-L_{radio} relation could be vital for defining robust observation requests.

How does the transition from an obscured to unobscured state correlate with AGN feedback and SMBH growth? As suggested by the low AGN fraction in the *Chandra* Deep Fields, a significant population of obscured AGN must exist at higher redshifts. One method of selecting unbiased samples of these objects is to assemble catalogs of candidate AGN using hard X-ray (*i.e.* NuStar), far-IR (*i.e.* SOFIA), and sub-mm (*i.e.* SCUBA-2) observations. Because current models suggest the luminous quasar population begins in an obscured state, and rapid SMBH mass growth is likely concurrent during this phase, understanding the transition from obscured to unobscured states is vital. How does accretion proceed and where does the accreting material come from: gas cooling out of the atmosphere? Gas

stripped from merging companions? Is accretion spherical and dictated by local gas density (*e.g.* Bondi)? A key component which has been neglected in AGN studies is the contribution of dust (which should be a significant component in the atmospheres of obscured AGN) in increasing the allowed Eddington luminosity for an accreting SMBH (*i.e.* $L_{\text{Edd.}} \propto \mu$). A curiosity which has emerged in recent years which may be interesting, particularly during the obscured stage when the merger rate is presumably high, is the role of multiple SMBHs within the core of a host galaxy. At a minimum, SMBH mergers occur on a timescale determined by dynamical friction, which for a typical dense bulge is $\gtrsim 1$ Gyr, which is $\gg t_{\text{cool}}$ of an obscuring atmosphere. If the SMBHs which are merging have their own accretion disks, then it is reasonable to question how the atmospheres surrounding a host galaxy with multiple AGN is affected, particularly since the transition from obscured to unobscured should proceed more quickly.

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[6] L. Bîrzan, B. R. McNamara, P. E. J. Nulsen, C. L. Carilli, and M. W. Wise. Radiative Efficiency and Content of Extragalactic Radio Sources: Toward a Universal Scaling Relation between Jet Power and Radio Power. *ApJ*, 686:859–880, October 2008.

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[11] K. W. Cavagnolo, M. Donahue, G. M. Voit, and M. Sun. Intracluster Medium Entropy Profiles for a Chandra Archival Sample of Galaxy Clusters. *ApJS*, 182:12–32, May 2009.

[12] K. W. Cavagnolo, M. Donahue, G. M. Voit, and M. Sun. Bandpass Dependence of X-Ray Temperatures in Galaxy Clusters. *ApJ*, 682:821–834, August 2008.

[13] G. M. Voit, K. W. Cavagnolo, M. Donahue, D. A. Rafferty, B. R. McNamara, and P. E. J. Nulsen. Conduction and the Star Formation Threshold in Brightest Cluster Galaxies. *ApJ*, 681:L5–L8, July 2008.

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