Active Galactic Nuclei: The Interplay between Supermassive Black Holes, Star Formation, and Galaxy Evolution

We propose a three-week Aspen Workshop in Summer 2008 on "Active Galactic Nuclei: The Interplay between Supermassive Black Holes, Star Formation, and Galaxy Evolution". Supermassive black holes surrounded by accreting disks of matter power the non-thermal emission from Active Galactic Nuclei (AGN). During the past decade, our understanding of the connection between Active Galactic Nuclei and their host galaxies has changed drastically: (1) it is now established that supermassive central BHs are hosted in both active and normal galaxies (e.g., Magorrian et al. 1998); (2) the BH mass ($M_{BH}$) directly correlates with the mass and velocity dispersion ($\sigma$) of the bulge of the host galaxy (Gebhardt et al. 2000; Ferrarese & Merritt 2000, Mathur et al. 2005, Kauffmann et al. 2007), suggesting a joint evolution of galaxies and their central BHs; (3) these correlations are identical for normal and active galaxies (McLure & Dunlop 2002). These observations strongly suggest that AGN activity may be a key phase in the life-time of any galaxy, rather than being a peculiarity of a small fraction of galaxies.

State-of-the-art numerical simulations link AGN activity to galaxy interactions and mergers. These simulations are based on the Toomre (1977) sequence in which two spiral galaxies lose their mutual orbital energy and angular momentum to tidal features and/or an extended dark halo and coalesce into a single galaxy. As the merger progresses, the galaxy disks may become disrupted by tidal effects, causing strong gas flows down the spiral arms and into the central regions of the merger. There, various mechanisms (i.e. starburst, nested bars, etc.) have been proposed to funnel the fuel into the central parsec and activate the AGN (Sanders & Mirabel 1996, Hopkins & Hernquist 2006). Once activated, AGN feedback may expel gas from the nucleus and suppress star formation (e.g., Springel, Di Matteo & Hernquist 2005, Ho 2005, Hopkins et al. 2006). Evidence for large-scale flows has recently been observed in galaxy pairs and merging galaxies (e.g., Kewley, Geller & Barton 2006, Martin 2006).

The development of these advanced numerical simulations allows, for the first time, detailed comparisons to be made between observations and theoretical predictions of AGN evolution. The energy output from the central supermassive black hole is now recognized to play a major role in the evolution of galaxies and galaxy clusters (Heckman & Kauffmann 2006). However, the actual physical processes and their duty cycles remain largely unknown. Furthermore, the physical link between AGN, star-formation, and gas flows on either a nuclear or global scale is unknown.

Summer 2008 is the ideal time to bring together the leading experts in radio/infrared/optical/X-ray observations, numerical simulations and theory to (1) compare recent observational studies with theoretical predictions on the connection between AGN, star-formation, and galaxy evolution, and (2) resolve the exciting and controversial issues in this field. Thanks to new large/shallow and small/deep multi-wavelength surveys (e.g., SDSS, GOODS, COSMOS), we now have the opportunity to combine theory and observations to generate the first robust understanding of the role played by AGN in galaxy formation and evolution. Recent technological advances and substantial progress in numerical simulations enables us to gain unprecedented insight into these issues. In particular, during the past couple of years the following advances have been made:

- LASER Adaptive Optics now provides high resolution images of star formation and nuclear activity in active galaxies (e.g., Ghez et al. 2005; Guyon, Sanders & Stockton 2006).
- Spitzer IRS, Mid Infrared Spectroscopy with Gemini, and hard X-Ray Observations with Suzuku now
probe even the most dust obscured nuclei (e.g., Armus et al. 2007).

- Recent soft X-ray observations have shown the importance and distinction between quasar feedback and radio feedback (e.g., Rafferty et al. 2006)
- Substantially improved hardware and software have enabled significant progress in numerical simulations of coalescing binary, supermassive black holes, galactic mergers, and cosmological simulations (e.g., Springel 2005)

Despite these significant advances in instrumentation and numerical simulations, there has been no forum to discuss and resolve the outstanding problems, discrepancies and lack of understanding of AGN and their link to star-formation and galaxy evolution. Most previous and future planned international meetings on black holes or active galactic nuclei either focus narrowly on the evidence for or the physics of black holes (e.g. IAU Symposium 238 “Black Holes”, “Central Engine of AGN” Xian Oct 2006), or they focus entirely on the large-scale relationship between the black hole and the host galaxies (e.g., IV POTSDAM Thinkshop, Sept 2006, KITP Workshop “Physics of Galactic Nuclei”, June 2006). Galaxy evolution meetings such as the Aspen meeting “Galaxy Evolution from Large Surveys” have not discussed the interplay between AGN, star-formation, and galaxy evolution in detail because it is difficult to make progress on such a large topic in a single discussion session.

No meetings thus far discuss the detailed relationship between active galactic nuclei, star formation and galaxy evolution. Because (1) substantial recent progress has been made in this field and (2) new discussions and collaborations are essential for resolving the many outstanding issues, a 3-week Aspen style meeting is timely and crucial. We anticipate that the first week will focus on recent multi-wavelength observational and theoretical work on the connection between star formation, merging and AGN fuelling in the nearby universe. During the second week we will discuss the nature of QSO host galaxies and the co-evolution of the host galaxy with the black hole. During the third week we will investigate the recent progress in our understanding of AGN and galaxy evolution over cosmological timescales. This third week discussion will include how the AGN environment and the $M_{\text{BH}} - \sigma$ relation change with redshift. Specific questions that this workshop will address include:

- Is there a connection between star formation and the fuelling of AGN activity? Recent merger models predict a direct link between star formation and AGN. Does observational evidence support these predictions? Is there observational evidence for AGN fuelling triggered by merging galaxies, as suggested by theory?
- How strong are gas flows inside the galaxy and from eventual companions towards the AGN? Are there observational signs for inflow of gas towards the nucleus? theoretical simulations predict substantial flows of gas towards the nucleus to fuel star formation and AGN activity.
- Where do the AGN host galaxies lie in the Tully–Fisher diagram or in the fundamental plane, i.e. do they lie on the scaling relations defined by normal, non–AGN galaxies?
- How does the AGN environment and $M_{\text{BH}} - \sigma$ relation change with redshift? How do these results compare with theoretical predictions?
- How important is AGN feedback to galaxy evolution and star formation?
- What observations should be made with the next generation of telescopes/facilities (e.g., GLAST, ALMA, TMT) to significantly advance our understanding of the relationship between AGN and galaxy evolution? What instrument parameters are required for such an advance in understanding?
Participation of Key Experts
Besides the SOC, the following key experts have enthusiastically agreed to participate in this meeting for the full three weeks, if the meeting is approved. Many of these experts noted in their agreement to participate that this meeting is needed, important, and timely. We would be happy to provide the participation agreement emails if required.

1. Tim Heckman (Johns Hopkins University)
2. Andrea Ghez (UCLA)
3. Lars Hernquist (Harvard Observatory)
4. Guenther Hasinger (Max-Planck-Institute for Extraterrestrial Physics, Garching, Germany)
5. Volker Springel (Max Plank Institut fur Astrophysik, Garching, Germany)
6. Colin Norman (Johns Hopkins University)
7. Luis Ho (Carnegie Observatories)
8. Carlos Frenk (Univ. of Durham, UK)
9. Laura Ferrarese (Herzberg Institute of Astrophysics, National Research Council of Canada)
10. Smita Mathur (Ohio State University)

Many other important experts also expressed a strong interest in attending this meeting for 2-3 weeks, including Lee Armus (Caltech), Andrew Benson (Caltech), Frank Bertoldi (Max-Planck-Institut fur Radioastronomie, Germany), Andrea Comastri (Osservatorio Astronomico di Bologna, Italy), Michael Dopita (Australian National University), Martin Elvis (Smithsonian Astrophysical Observatory), Mauro Giavalisco (Space Telescope Science Institute), Garth Illingworth (U. California, Santa Cruz), Andrey Kravtsov (U. Chicago), Julian Krolik (Johns Hopkins University), Roberto Maiolino (Osservatorio Astrofisico di Arcetri, Italy), Milos Milosavljevic (University of Texas), Norman Murray (CITA), Hagai Netzer (Tel Aviv University, Israel), Eliot Quataert (Berkeley), Alan Stockton (U. Hawaii), Todd Thompson (Princeton University), Tomaso Treu (U. California, Santa Barbara), Meg Urry (Yale University), Risa Welchler (Stanford), Rosie Wyse (Johns Hopkins University). This strong show of support from many experts in the field underlines the timeliness of a 2008 Aspen meeting to discuss the connection between AGN, star formation, and galaxy evolution.

We submitted a similar meeting proposal for the heavily oversubscribed 2007 summer session. We were strongly encouraged to resubmit our proposal for 2008. Our first priority time slot is July/August. Some of the women on our SOC and experts list have school-aged children, and have requested July/August to avoid conflicts with the school academic year.

SOC
The scientific organizing committee for this meeting is composed of
Dr Lisa Kewley (University of Hawaii; kewley@ifa.hawaii.edu; 1-808-772-0079),
Dr Mara Salvato (California Institute of Technology; ms@astro.caltech.edu; 1-625-395-2587),
Dr Guinevere Kauffmann (Max Planck Institut fur Astrophysik; gamk@mpa-garching.mpg.de; +089 30000-2013),
Prof. Crystal Martin (University of California, Santa Barbara; cmartin@physics.ucsb.edu; 1-805-893-8760)

Contacts
Lisa Kewley is the designated SOC contact, and Mara Salvato is responsible for ensuring diversity.

References
Heckman, T. & Kauffmann, G. 2006, NewAR, 9, 677