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

We propose a three-week Aspen Workshop in Summer 2007 on "Active Galactic Nuclei: The Interplay between Supermassive Black holes, Star Formation, and Galaxy Evolution". Supermassive black holes (BHs) powered by accretion disks are held to be the engines of the non–thermal emission of Active Galactic Nuclei (AGN). During past 15 years, our understanding of the connection between Active Galactic Nuclei and their host galaxies has changed dramatically: 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 (\( M_{\text{BH}} \)) directly correlates with the mass and velocity dispersion (\( \sigma \)) of the bulge of the host galaxy (Gebhardt et al. 2000; Ferrarese & Merritt 2000), 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 could be simply an event, potentially recurrent, in the life-time of any galaxy, rather than being a peculiarity of a small fraction of galaxies.

The most widely supported AGN evolutionary scenario is based on the Toomre (1977) sequence in which two galaxies lose their mutual orbital energy and angular momentum to tidal features and/or an extended dark halo and coalesce into a single galaxy. Tidal interactions and associated shocks are thought to trigger star formation (e.g., Bushouse 1987, Barnes 2004). As the merger progresses, the galaxy disks may become disrupted by tidal effects, causing strong gas flows inwards to the central regions where kpc-scale starbursts may be fueled (Barnes & Hernquist 1996) and the AGN phase activated (Sanders & Mirabel 1996, Hopkins et al. 2006). Theory suggests that once activated, AGN feedback may expell gas from the nucleus and suppress star formation (e.g., Granato et al. 2004, Cattaneo et al. 2005, Hopkins et al. 2006, Crotton et al. 2006).

The development of these advanced models allows, for the first time, detailed comparisons to be made between observations and theoretical predictions of AGN evolution. The energy output from central supermassive black hole is now recognized to play a major role in the evolution of galaxies and galaxy clusters. 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 2007 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 new opportunity to combine theory and observations to generate a solid understanding of AGN and their role 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 data on star formation and nuclear activity in active galaxies.
- Spitzer IRS, Mid Infrared Spectroscopy with Gemini, and hard X-Ray Observations with Suzaku now probe even the most dust obscured nuclei.
• Recent soft X-ray observations have shown the importance and distinction between quasar feedback and radio feedback.

• Substantially improved hardware and software have enabled significant progress in numerical simulations of coalescing binary, supermassive black holes, galactic mergers, and cosmological simulations.

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 progress has been made in this field in the past couple of years and (2) new discussions and collaborations are essential for resolving the many outstanding issues, a 3-week Aspen style meeting is important and timely. 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 do the AGN environment and $M_{\text{BH}} - \sigma$ relation change with redshift? How do these results compare with theoretical predictions?

• Are the differences between AGN classes a result of different geometric viewing angles or are the classes related in an evolutionary sense?

• How important is AGN feedback to galaxy evolution and star formation?

This meeting is complementary to the Summer 2007 meeting proposal on “Galaxy Clustering” by Joanne Cohn and collaborators. A schedule overlap with the galaxy clustering meeting would be advantageous to both groups, enabling experts from both fields to interact and discuss overlapping areas. In particular,
overlap with the galaxy clustering meeting would facilitate a joint session between the two groups on AGN environment and clustering.

**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. Volker Springel (Max Plank Institut fur Astrophysik, Garching, Germany)
3. Martin Elvis (Smithsonian Astrophysical Observatory)
4. Laura Ferrarese (Herzberg Institute of Astrophysics, National Research Council of Canada)
5. Carlos Frenk (Univ. of Durham, UK)
6. Lars Hernquist (Harvard Observatory)
7. Michael Dopita (Australian National University, Canberra, Australia)
8. Andrea Comastri (Osservatorio Astronomico di Bologna, Italy)
9. Smita Mathur (Ohio State University)
10. Daniela Calzetti (Space Telescope Science Institute)

Many other important experts have also expressed a strong interest in attending this meeting for 2-3 weeks, including Julian Krolik (JHU), Dave De Young (NOAO), Colin Norman (JHU), Luis Ho (Carnegie Observatories), Eva Schinnerer (Max Plank Institut fur Astrophysik, Germany), Lee Armus (Caltech), Hagai Netzer (Tel Aviv University, Israel), G. Luigi Granato (Osservatorio Astronomico di Padova, Italy), Frank Bertoldi (Max-Planck-Institut fur Radioastronomie, Germany), Alan Stockton (U. Hawaii), Roberto Maiolino (Osservatorio Astrofisico di Arcetri, Italy), Mauro Giavalisco (Space Telescope Science Institute), Maria Polletta (UC San Diego), Anton Koekemoer (JHU). This strong show of support from many experts in the field underlines the timeliness and need for an Aspen meeting to discuss the connection between AGN, star formation, and galaxy evolution.

**SOC**

The scientific organizing committee for this meeting is composed of
Dr Lisa Kewley (Hubble Fellow, University of Hawaii; kewley@ifa.hawaii.edu; 1-808-772-0079),
Dr Mara Salvato (S-COSMOS Postdoctoral Fellow, California Institute of Technology; ms@astro.caltech.edu; 1-625-395-2587),
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**Time Constraints**

We would prefer this workshop to be scheduled between June 24 - August 31 due to teaching constraints in June. Lisa Kewley (kewley@ifa.hawaii.edu) is the designated SOC contact person, and Mara Salvato (ms@astro.caltech.edu) is the person responsible for ensuring diversity among participants.