SKA Science Working Group 5
Active Galactic Nuclei and Supermassive Black Holes

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Working group members:

Dayton Jones (chair), Luigina Feretti, Colin Lonsdale, Gabriele Giovannini, Andrei Lobanov, Ken Kellermann, Carole Jackson, Hisashi Hirabayashi, Franco Mantovani, Richard Porcas, Doris Neumann, Paola Parma, Gianfranco Brunetti, Daniele Dallacasa, Tiziana Venturi, Leonid Gurvits, Rustam Dagkesamanskii,Maria Marcha, Matteo Murgia, Shinji Horiuchi, Dave Meier,Frazer Owen, Jim Ulvestad, and Mike Garrett.

Science Goals

High-level science goal: follow the evolution of super massive black holes in the universe through the central role they play in active galactic nuclei

Table 1. Level 1 Science Goals

Level 1	**Maximum Baseline (km)**	**Frequency Range (GHz)**
The Genesis of AGN		
Detectin of the first epoch of AGN and Starburst Activie	> 2000	1 - 5
AGN Evolution		
Radio Lumosity function for all luminosity levels and all redshifts	> 2000	1 - 5
Understand physical basis of FR I/II and radio loud/quiet QSO dichotomies	~5000	1 – 36
Physics of AGN		
Distribution of Brightness Temperatures and all luminosities	~5000	1 – 36
Properties of inner accretion disks	~5000	0.3 – 22
Relativistic Outflows	~5000	1 - 36

Table 2. Level 2 Science Goals

Level 2	Maximum Baseline (km)	Frequency Range (GHz)
AGN Evolution		
Ages of young radio sources from sizes of Thompson scattering halos	500	0.3 - 5
Jet/ISM interactions	>2000	0.3 – 5
Extended radio lobes	500	0.3 – 3
Other		
Astrometry and geodesy	~5000	5 – 36
Multi-wavelength all-sky surveys with full polarization information	>500	0.3 - 36

N.B. - These 'other' goals are not necessarily any less important than our level 1 goals, but they do not fit directly into the specific AGN science area. Nevertheless, they should not be overlooked.

General Considerations:

A scale-free array configuration (self-similar, ‘zoom’ array) is strongly favored for all science goals that require spectral index imaging. This is particularly important for studies of AGN, whose spectra are often complex and time-varying, and whose radio emission spans angular scales from sub-mas to degrees.

A continuum sensitivity (rms noise) of 100 nJy in 15 minutes of observing is sufficient for all of the science goals listed above.

Discussion

The "Genesis of AGN" topic is concerned with the epoch of initial AGN activity and whether this occurred before the first starburst activity, after it, or simultaneously with it. The primary SK requirement is to be able to distinguish thermal from nonthermal compact radio sources at high redshift. This means an angular resolution of a few mas at a few GHz and the ability to detect sources of about 1 micro-Jy.

There are two types of observation listed under "AGN Evolution". First, we want to determine the radio luminosity function for sources in all luminosity classes, and see how this changes as a function of redshift. Presently we can do this only for the most luminous sources, and even for them the luminosity function is not very well determined due to the small sample size. This is not a challenging goal for the SKA, requiring neither very high angular resolution nor very wide frequency coverage. The second type of observation is more difficult, but absolutely critical if we are to understand what AGN are in general and not only the radio-loud subset. We need to image

AGN that have very low radio luminosities (radio-quiet quasars) with sufficient sensitivity and angular resolution to compare their morphology with that of radio-loud AGN. This should provide our best clues to why some objects containing super massive black holes are orders of magnitude more (or less) efficient in producing radio emission. Is the radio emission in radio-quiet quasars still coming primarily from jets? If so, why are these jets so much fainter than those in other AGN? This is likely related to the question of why FR-I and FR-II radio galaxies differ in the types of jets they produce. Our ultimate goal is to compare high-resolution observations of a wide range of objects containing super massive black holes to determine what the important physical difference in the "central engine" is - black hole mass, black hole spin, magnetic field strength, inner accretion disk geometry, surrounding gas density, binary black holes, or something we haven't thought of yet?

These observations will require the highest possible angular resolution and the highest possible observing frequencies, since the closer to the base of the jets we can image the more likely we are to see direct evidence of why the jets differ so much in their radio brightness.

The "Physics of AGN" topic contains three types of observation. The distribution of core brightness temperatures as a function of source luminosity and redshift tells us directly how the role of relativistic beaming evolves with time. The properties of the inner pc of accretion disk surrounding super-massive black holes can be studied via free-free absorption imaging (requiring a challenging combination of high resolution at low frequencies) and water megamaser dynamics (requiring high resolution at 22 GHz to separate different maser features within the disk). Finally, the detailed study of relativistic outflows (jets) will continue to be central to understanding the physical processes operating in the immediate vicinity of super massive black holes. Current VLBI studies of extragalactic jets are hampered by our inability (in all but a few favorable cases) to obtain enough resolution to have multiple beams across the width of a jet, and thus to be able to image the internal jet structure and compare this with the results of numerical simulations of relativistic jets. The great sensitivity of the SKA will allow even steep-spectrum jet emission to be imaged at the highest frequencies, more than compensating for SKA's inability to exceed the baseline length of current VLBI arrays. In addition, the sub-pc structure in low luminosity objects will be detectable, allowing comparisons of jet morphology (and its evolution) as a function of radio emission efficiency. This will shed light on the differences in jet formation between high and low radio luminosity AGN.

Radio jets extend over a very wide range of angular scales, from sub-mas to degrees in the more extreme cases. They represent the bulk transport of matter and energy over huge distances, and can influence the temperature and magnetic field strength in galaxy cluster halos and even influence the formation and evolution of more recent generations of radio galaxies. Understanding the energetics, stability, and internal flows of radio jets requires high dynamic imaging over as much of the angular range covered by jets as possible, and consequently favors an array configuration with the widest possible range of baseline lengths.