

The formation and evolution of galaxies IV: The relation between galaxy evolution and AGN

Program contacts: Simon Lilly, Mike Fall, Massimo Stiavelli, Piero Madau, Avi Loeb, Jon Gardner, Marcia Rieke, Bob Fosbury
Scientific category: DISTANT GALAXIES
Instruments: OPT/CAM, NIR/CAM, NIR/SPEC
Days of observation: 66

Abstract

There is already significant observational evidence for a link between quasar/AGN activity and the general evolution of galaxies: (a) most if not all massive galaxies harbour massive black holes in their cores that were likely to have been quasars in the past; (b) the most luminous manifestations of AGN activity appear to be linked in the present-day universe to mergers of galaxies, a process that is central to the hierarchical picture of galaxy formation; (c) the cosmic evolution of the quasar population appears to be similar to that inferred for the global star-formation history of the universe. However, the physical nature of this link, and even whether it is direct or indirect, is not understood. The principal objectives of this proposal are to compare AGN hosts with the rest of the galaxy population and elucidate any dependencies on AGN type and environment. We will exploit the presence of an AGN to perform more sensitive studies of the host environment than can be achieved for non-active galaxies, ie. chemical composition of the ISM and gas kinematics at large R/R_e . For ‘type 2’ active objects, eg. radio galaxies, where the AGN is obscured from direct view by material within the galaxy, the ‘natural coronagraph’ will allow observations of the host galaxy which are directly comparable to the data that will be obtained on the general field and cluster galaxy populations.

Observing Summary:

| Target | RA | Dec | K_{AB} | Configuration/mode | Days |
|------------------|-----|-----|-----------|--------------------|------|
| IMAGINGX8 | TBD | TBD | 33 at I | OPT/CAM R3 | 4 |
| IMAGINGX8 | TBD | TBD | 32.5 at L | NIR/CAM R3 | 7 |
| DIAGNOSTICX8 | TBD | TBD | 27 at L | NIR/SPEC R1000 | 11 |
| KINEMATICX8 | TBD | TBD | 27 at L | NIR/SPEC R10000 | 11 |
| IMAGINGX8 | TBD | TBD | 33 at I | OPT/CAM R3 | 4 |
| IMAGINGX8 | TBD | TBD | 32.5 at L | NIR/CAM R3 | 7 |
| DIAGNOSTICX8 | TBD | TBD | 27 at L | NIR/SPEC R1000 | 11 |
| KINEMATICX8 | TBD | TBD | 27 at L | NIR/SPEC R10000 | 11 |
| Grand total days | | | | | 66 |

■ Scientific Objectives

Scientific Objectives

Quasars were the first objects to be discovered at cosmologically significant redshifts and the evolution of the quasar population (there were many more quasars of a given luminosity at earlier epochs) constituted some of the first direct evidence that we live in an evolving universe. In parallel, the evidence that quasars and other AGN represent superluminous activity associated with massive collapsed objects in the nuclei of galaxies has become very strong, leading to speculations about the links between AGN and the evolution of galaxies. The existence of massive black holes in the nuclei of most massive galaxies in the local universe suggests that AGN activity may be a phase that most (if not all) galaxies go through, including our own Milky Way. Furthermore, in the local universe, ultra-luminous IRAS galaxies, which in some cases harbour AGN, appear to be triggered by major merger events, a process that many galaxies may have undergone at earlier times. Possible connections between QSO evolution and the evolution of galaxies are also indicated by the recent indications that the overall luminosity density of the universe at ultraviolet wavelengths follows an evolution with redshift that is remarkably similar to that inferred for QSO.

Thus the circumstantial links between these phenomena are quite strong. However, despite these suggestive pieces of evidence, the physical nature of any links between AGN activity and the formation and evolution of galaxies remain unclear. We do not know whether the presence of an AGN stimulates or inhibits star-formation activity in the galaxy. Even more profoundly, we do not know when massive black holes first appeared in the universe and whether they arose as the result of stellar evolutionary processes in dense stellar environments (the cores of massive galaxies) or whether they pre-dated (or even triggered) the formation of such galactic cores. In short, we do not know whether galaxy formation/evolution and the AGN phenomena are basically different phenomena responding to the same stimuli, or whether they are intimately connected.

Different observational techniques can be used for the different classes of AGN. For QSO's in general, the strategy requires a careful discrimination against the bright AGN source in order to reveal the underlying galaxy properties. This places stringent demands on the imaging properties of the telescope and may require the use of coronagraphic techniques. For 'type 2' objects, however, the obscuration of the nucleus by part of its own circumnuclear environment provides a 'natural coronagraph' which, in the case of the powerful radio galaxies — thought to be identical to the radio quasars other than in orientation with respect to our line of sight — facilitates a quite detailed investigation of the galaxy and its ISM. In contrast to their non-active counterparts, part of the ISM of these type 2 objects is illuminated by the AGN and consequently subject to more detailed physical study than would otherwise be the case. In particular, and subject to a reasonable understanding of the ionization mechanism, the chemical composition of the ISM can be deduced from measurements of the emission lines. This is currently being attempted for radio galaxies at redshifts near the peak of the AGN space density curve but even here, and certainly at higher redshifts, the best lines for abundance analysis are shifted into the IR where NGST

spectroscopy is the only practical tool for a complete study. Early results with Keck optical spectroscopy show substantial variations in composition which may indicate different, but relatively early, stages of evolution of a massive starburst when the particular AGN ‘switches on’.

The present proposal seeks to determine the nature of the links between AGN activity and the general evolution of galaxies. Our proposed strategy is to observe galaxies hosting AGN, or existing close to AGN, at high redshifts ($z \geq 2$) using the same techniques as applied to ‘normal’ field and cluster galaxies in the DRM imaging and spectroscopic surveys. This will allow comparisons to be made in the detailed properties of the galaxies. While the field surveys of random parts of the sky will detect quite large numbers of low luminosity AGN, they will not cover sufficient volume to yield large numbers of the more luminous examples, and these systems must be studied with pointed observations at previously identified AGN. Surveys such as the SDSS will produce large well-defined samples of quasars in the $19 < V < 24$ range at high redshift $z \sim 4$. Surveys at radio, X-ray and, possibly IR wavelengths will produce samples of type 2 AGN.

Intensive studies of the fields of bright AGN have the additional advantage that the quasar light can be used to probe the intergalactic medium along the line of sight. Ground-based spectroscopy of such systems will detect absorption line systems due to Lyman- α and heavy elements at lower redshifts, which can then be associated with galaxies at the same redshifts.

■ NGST Uniqueness/Relationship to Other Facilities

Observations of the rest-frame UV spectrum (Ly- α – CIII]) are required to detect and characterise any young stellar population in the host. It is here that the strongest photospheric and stellar wind absorption lines in OB stars are to be found. For redshifts less than about 3.5, this problem can be tackled quite successfully using large groundbased telescopes where the additional use of polarimetric observations allows a separation to be made between the stellar and scattered AGN continua. For AGN hosts significantly earlier than the space density peak at $2 \leq z \leq 3$, however, the faintness and sky background render such observations impractical.

Observations of the rest-frame visible spectrum can be made from the ground until the H α – [SII] region moves beyond the *K*-band at $z \approx 2.5$. The NGST core bandpass enables spectroscopy to continue to $z \approx 6$.

In addition to the necessity to cover wavebands not practically accessible from the ground, high contrast imaging — of a quality unlikely to be available from AO techniques especially at the shorter wavelengths — is required to discriminate the host properties from direct contamination by the AGN and to isolate spatially the actively star-forming regions. For the type 1 objects, coronagraphic techniques for both imaging and spectroscopy, would be a valuable additional capability.

Please see also the associated imaging and spectroscopic survey DRM proposals.

■ Observing Strategy

We propose to observe a sample of eight very luminous quasars and 8 fainter quasars at the highest possible redshifts, with observations that are as similar as possible to those of the field surveys. Not only will this allow us to relate the properties of the host and companion galaxies to those of the field samples, but the properties of the absorbers along the line of sight to the eight bright quasars can be also be related to those of the field sample in as much detail as possible. These fields will be imaged in the same filters as the imaging survey, at the depth of the ‘wide’ flanking fields (exposure time 3.5 days in each field). Two masks in each field will be observed in the R=1000 and R=10,000 modes (see spectroscopic DRM proposal) to yield detailed data on around 200 galaxies (exposure time 4.5 days in each field). These observations will thus reach the same depth as the ‘field galaxy’ programs.

■ Special Requirements

Maximum FWHM: 100 mas at $2 \mu\text{m}$
 Minimum FOV: $2'$ at 1-5 μm
 RMS offset accuracy: 15 mas
 RMS repointing accuracy: 15 mas

■ Precursor/Supporting Observations

The target quasars must be found, but this will not be a problem.