DES Standard External Collaborator Application

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Project Title: QSO Reverberation Mapping

Contact and Sponsor: Paul Martini (martini@astronomy.ohio-state.edu)

External Collaborators: Tamara Davis (University of Queensland), Stephen Fine (University of Sydney), and Rob Sharp (Australian National University)

Working Group: Quasars

Executive Summary

This document outlines a proposal[1] from Paul Martini of Ohio State (co-chair of the DES QSO WG) for Tamara Davis, Stephen Fine, and Rob Sharp to become External Collaborators (hereafter the ECs) on projects related to the use of reverberation mapping to estimate black hole masses for QSOs in the DES SN fields. The three candidates would contribute substantial spectroscopic data, in the form of AAT observations with AAOmega, as well as analysis expertise. These contributions would enable significant new science results that could not be obtained from the DES imaging data alone, nor could readily be obtained with any other spectroscopic facility. These spectroscopic data are the same data described in the OzDES Broad Scope External Collaborator Proposal, but this scientific application was not covered in that proposal.

Scientific Motivation and Goals

The masses of supermassive black holes in Active Galactic Nuclei (AGN) are arguably their most fundamental physical property. The mass, along with the accretion rate and perhaps the spin, appear to uniquely determine the spectral energy distribution and thus all observational properties. In addition, the supermassive black hole mass for all luminous galaxies in the local universe, and not just AGN, appears to be well correlated with host galaxy properties, most notably the spheroid stellar mass and velocity dispersion (Ferrarese & Merrit 2000; Gebhardt et al. 2000). The presence of this correlation implies that black holes and their host galaxies have co-evolved over cosmic time, perhaps due to feedback between black hole and galaxy growth.

At present about 50 galaxies total have supermassive black hole mass estimates (in the range $10^{7\text{-}9}$ solar masses) based on direct measurements of stellar or gas kinematics within the black hole's sphere of influence (e.g. Gultekin et al. 2009). A comparable number of AGN have high-quality (factor of two to three uncertainty) black hole mass estimates based on reverberation mapping (and there is a small amount of overlap between these two samples). However, essentially all of these black hole mass estimates are for inactive or low-luminosity AGN ($L_{bol}<10^{45}$ erg/s) in the local universe. Luminous QSOs, whose black hole masses are growing the fastest, and galaxies at high redshift ($z>1$), where the bulk of both black hole and galaxy growth occurred, have largely not

[1] This proposal is based on the membership policy dated 6 Dec 2011 and available at https://www.darkenergysurvey.org/reports/membership_policy_revised-Dec-2011.pdf

been studied with the most robust methods. This is because reverberation mapping requires regular, long-term monitoring to yield results. This monitoring is required because the goal of reverberation mapping is to measure the physical size of the broad line region, which may range from light weeks across up to a light year for the most luminous QSOs (e.g. Peterson 2011). The size is measured as the time lag between continuum and broad line luminosity variations in AGN, so measurement of the time lag often requires monitoring for at least this long, and sometimes two to three times longer, to detect a clear signal. The enclosed mass may then be determined with a measurement of the broad line velocity profile and application of the virial theorem.

The DES SN fields are extremely well suited to apply reverberation mapping to estimate black hole masses for both high-luminosity QSOs and high-redshift QSOs (up to z=3). This is for three reasons: 1) The DES SN fields will have approximately weekly imaging for approximately five months each year. This cadence is more than sufficient to identify QSOs that have exhibited a substantial continuum variation, and are therefore good targets for spectroscopic monitoring; 2) The continuum monitoring will continue for five more years (plus the one year already in hand), which is well-matched to measure the lag times expected for even the most luminous QSOs at high redshift; 3) The planned AAT spectroscopy of the SN fields would target them approximately monthly from September through January (the present plan is three times the first year, and four times in the subsequent four years). The AAOmega spectrograph has substantially more fibers than there are bright QSOs (or SN in any given month), so a substantial step forward in the field of high-redshift black hole masses may be made for a very modest investment of fibers.

The ECs plan to apply a 'stacked' reverberation mapping approach (that they developed, see Fine et al. 2012) to these data. They plan to target several hundred QSOs with ($L_{bol}=10^{45-47}$ erg/s) approximately twice a year to estimate the reverberation lags for classes of objects, for example binned in luminosity. There are three specific applications that they wish to pursue: 1) measurement of the relationship between the broad line region radius and QSO luminosity for the MgII and CIV lines (the radius-luminosity relationship); 2) estimate black hole masses for samples of QSOs at different luminosities and redshifts; 3) better quantify how well the radius-luminosity relationship could be used as a standard candle for cosmology (Watson et al. 2011). This investigation and analysis is largely distinct from the interests of members of the QSO WG, whose primary interest was reverberation mapping of individual, luminous QSOs with spectroscopic monitoring every time the fields are observed with the AAT. In practice, both together will lead to sufficient dynamic range in luminosity to determine the radius-luminosity relationship for these two broad lines and numerous applications. Our expectation is that the ECs and QSO WG members would work together on these reverberation mapping topics and share leadership on the science results. The QSO WG has discussed and endorses this proposal, as it will produce substantially new and unique scientific return from the DES data.

Details of the Agreement

The ECs and the QSO WG have agreed to the following principles to define this collaboration, which largely mirror those in the OzDES Broad Scope External Collaborator Proposal to join the SN WG:

1. The ECs will manage the entire process of collecting data from the AAT. This includes applying for telescope time, obtaining and processing the data, and making the data available to the DES collaboration. (These are the same data products already described and covered by the OzDES request.)
2. DES will provide the ECs with the photometric data necessary to study the continuum variability of the QSOs from the DES imaging data. This is presumed to be catalog-level data products.
3. This agreement does not exclude the ECs from applying to become full members of DES in the future, or applying to join other WGs as external collaborators, although that would require a separate proposal.
4. Up to one student and one postdoc may work under the direct supervision of each EC on the projects covered by this proposal. The QSO WG and the ECs will maintain a list of these students and postdocs.
5. The ECs will be encouraged to participate in the regular telecons of the QSO WG, as well as the DES collaboration meetings.
6. Publications that use AAT spectroscopy obtained as part of the OzDES collaboration will be covered by the OzDES Broad Scope External Collaborator Proposal.
7. The ECs agree to abide by the Membership and Publication Policies of DES and the Principles for the Organization and Management of DES Science Projects.
8. This agreement will hold so long as the agreement associated with OzDES Broad Scope External Collaborator Proposal remains active.