IX SERBIAN CONFERENCE ON SPECTRAL LINE SHAPES IN ASTROPHYSICS
May 13-17, 2013, Banja Koviljača, Serbia
Book of Abstracts, Eds. L. Č. Popović, M. S. Dimitrijević, Z. Simić and M. Stalevski
Astronomical Observatory Belgrade, 2013

USING AGN BROAD EMISSION LINES TO MEASURE BLACK HOLE MASSES

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The gas responsible for emitting the characteristic broad emission lines observed in AGN spectra is photoionized by high-energy continuum photons emitted by the thermal accretion disk surrounding the black hole. The consequence is that changes are observed in the integrated line flux that mirror changes seen in the continuum flux, but after a time delay that corresponds to the mean light travel time between the central continuum source and this broad line-emitting gas in the "broad line region" (BLR). Measuring this time delay, or lag τ, between flux variations in the AGN continuum and broad emission-line light curves provides a measure of the BLR radius, $R_{\rm BLR} = c\tau$. This technique, known as reverberation mapping is used to measure the mass of the central black hole, but it is time and resource intensive. Luckily, $R_{\rm BLR}$ measurements made for $\sim$50 local AGNs provide means for estimating a black hole mass from the single epoch spectrum. This makes it possible to estimate black hole masses for large samples of objects across the observable universe. I will demonstrate how we use broad emission lines and reverberation mapping to measure black hole masses both directly and indirectly from single-epoch spectra. I will then discuss recent work that has uncovered the source of the systematic problems that exist for black hole masses based on the C IV λ1549 line, the emission line most applicable for studying black holes in the high-redshift universe. Finally, I show ways that these problems can be mitigated to produce reliable black hole mass estimates based on C IV. This work has significant implications for our understanding of black hole growth and the co-evolution of black holes and galaxies, as this evolution can be more precisely probed with better constraints on the observed black hole mass distributions at all redshifts.