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SUPER-EDDINGTON QUASARS: FROM ATOMIC PHYSICS TO COSMOLOGY

PAOLA MARZIANI

National Institute for Astrophysics (INAF),
Padua Astronomical Observatory, Padua, Italy
E–mail paola.marziani@inaf.it

Abstract. Quasars accreting matter at very high rates, known as extreme Population A (xA) or super-Eddington accreting massive black holes, represent a new class of distance indicators spanning cosmic epochs from the present-day Universe to less than 1 Gyr after the Big Bang. These quasars exhibit distinct observational properties, including a steep soft and hard X-ray continuum, strong singly-ionized iron emission, and extreme high-ionization line profile blueshifts. These characteristics not only make them easily recognizable but also indicate extreme physical properties compared to the general quasar population, such as very high metallicity and a strong high-ionization wind, likely associated with an optically thick, advection-dominated accretion flow.

In this review, we explore in detail the key optical and UV spectral properties of xA quasars, which facilitate their identification in large spectroscopic surveys from low to very high redshifts. We analyze the physical conditions responsible for the formation of their emission lines, focusing on the spectral energy distribution, ionization parameters, metallicity and density.

We address some puzzling aspects related to the formation and evolution of super-Eddington quasars. We emphasize that their importance extends beyond understanding quasar physics: their exceptionally high accretion rates enable these quasars to radiate at a stable, extreme luminosity-to-mass ratio. This stability results in consistent physical and dynamical conditions in the mildly ionized gas of the quasar low-ionization line-emitting region.

Our analysis ultimately supports the potential for identifying a virial broadening estimator based on the widths of low-ionization lines, such as the HI Balmer line Hβ and MgIIλ2798. The connection between line width and quasar intrinsic luminosity super-Eddington active galactic nuclei (AGN) is a reinstatement of a law that appears universal in the form $L \propto \sigma^n$, holding from stars to clusters of galaxies. In the case of AGN, the dominance of Keplerian motions and the restriction to a very limited range of Eddington ratio for the super-Eddington sources imply a well-defined scaling between luminosity and FWHM or σ with exponent $n \approx 4$, analogous to the 21cm line broadening that is due to (mainly) Keplerian motion in galactic disks. This approach offers a promising method for deriving redshift-independent luminosity estimates grounded in the known luminosity-to-mass ratio of these quasars. By establishing a reliable virial broadening estimator, under very stable physical and dynamical conditions of the emitting regions, we lay the foundation for the exploitation of super-Eddington sources as standard candles for cosmological distance measurements.