Abstract

The main goal of this thesis is to investigate the jet production efficiency in Active Galactic Nuclei (AGN), distinguishing between radio-quiet (RQ) and radio-loud (RL) AGNs. From radio observations we observe not only a significant scatter of these efficiencies (4-5 orders of magnitude) but also unusually large jet powers (P_j) among RL objects, sometimes exceeding their accretion powers ($P_{\rm accr} = \dot{M}c^2 = L_{\rm bol}/\epsilon_d$, where $L_{\rm bol}$ is the bolometric luminosity and ϵ_d is the radiative efficiency) of these AGNs. This in turn leads to four questions: (1) what exactly causes such a large range of jet production efficiencies ($\eta_j \equiv P_j/P_{\rm accr}$); (2) is there only one mechanism uniformly responsible for the production of jets we observe (among RQ and RL objects) or are there several different processes; (3) does the production of the strong jets observed in RL objects correspond to the crossing of a specific threshold(s); (4) how are the most powerful observed jets obtained?

The answers to the above questions have been sought after over the past five years of doctoral studies (2016-2021) through careful analyses of diverse sets of AGNs, presented in three peer-reviewed papers. Although these studies, when compared among themselves, may seemingly appear inconsistent (described below), from all the collected results and their theoretical considerations a coherent picture emerges that leads to the same conclusion – namely, not all AGNs are able to produce very strong jets, where the appropriate accumulation of the magnetic field at the center is an extremely important factor, as the only model explaining the existence of jets with the highest strengths is the magnetically arrested disk (MAD) scenario. In this model, jets are produced in the Blandford-Znajek mechanism, where they are powered by the rotational energy of the black hole, and the high efficiency of their production is ensured by the large flux of the magnetic field sustained on the black hole (BH) by the pressure of its accreting matter.

In Paper I, the jet production efficiencies were analyzed for four diverse sets of AGNs, whose common feature was the presence of a pair of FR II type radio lobes which provide the possibility of calculating their jet powers from the calorimetry of these lobes. A comparison of these objects showed a clear decrease in the jet production efficiency at higher accretion rates ($\lambda_{\rm Edd} \equiv L_{\rm bol}/L_{\rm Edd}$). Such a decrease, which could be explained by the transition from a radiatively inefficient, optically thin, but geometrically thick accretion disk to an optically thick and geometrically thin standard disk, which occurs for objects with moderate accretion rates ($\lambda_{\rm Edd} \sim 0.01$) where $P_j > L_{\rm bol}$ suggests the presence of MAD in these sources while assuming thicker accretion disks than the standard theory predicts.

In Paper II, we focused on studying the radio bimodality (i.e. the radio loudness distribution, $R = L_{\rm radio}/L_{\rm optical}$, illustrating $\sim P_j/L_{\rm bol}$) in one carefully selected and extremely homogeneous

sample of AGNs. Our research confirmed the bimodal distribution of radio loudness and revealed a deficit of jets with intermediate jet production efficiencies (calculated analogously to those in Paper I but with a limited number of objects with double radio lobes) implying the existence of a certain threshold(s) condition(s) for the production of the strongest jets. Finally we considered in detail various scenarios of the MAD formation.

In Paper III, we analyzed how the RL fraction (RLF) of quasars (QSOs) changes with cosmic time. In order to do so, as a first step, similarly to Paper II, we carefully selected the objects under study creating three subsets for which we found a decrease in RLF with an increase in redshift. Furthermore, by removing the bias implied by the dependence of RLF on the redshift by narrowing its range, we were able to examine more closely the dependence of RLF on BH mass and Eddington ratio finding an increase in RLF with an increase in $M_{\rm BH}$ and no dependence between RLF and $\lambda_{\rm Edd}$. Putting together all the results obtained in this work we get an even steeper decrease in RLF with redshift. We made an attempt at linking these findings with the possible scenarios of the MAD formation, with a focus on the types of galaxy mergers being responsible for triggering AGN activity.