Quasars as standard candles - PhD project

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We are now in the so-called era of "precision cosmology", as we can estimate cosmological parameters with precision of few percents. However, the redshift range between the furthest observed SNIa (z∼2) and the CMB (z∼1100) had been poorly tested due to the lack of reliable standard candles. In recent years, attention has been brought on the employment of quasars as standard candles, thanks to the nonlinear observed relation between X-ray and UV band luminosity $\log(L_X) = \alpha \cdot \log(L_{UV}) + \beta$: employing observed fluxes instead of luminosities, the luminosity distance of each quasar can be determined without assuming a cosmological model. Quasars constitute an important cosmological tool since they are numerous, very bright and currently detectable up to redshifts z∼7.

The in-depth study of the $L_X - L_{UV}$ relation is fundamental: the more solid it is proven to be, the more reliable the distance estimations and the resulting cosmological outcomes will be, making quasars more powerful cosmological probes. Furthermore, demonstrating that the link between L_X and L_{UV} is very tight and that the intrinsic dispersion of the $L_X - L_{UV}$ relation is low is important in order to fully validate this cosmological tool, even if we are still lacking a universally accepted physical model that explains the $L_X - L_{UV}$ relation.

One of the main issues that still affect the employment of quasars as standard candles is the observed dispersion of the $L_X - L_{UV}$ relation. In previous studies, it has been shown how the high observed dispersion (> 0.35 dex) can be reduced to 0.24 dex through an accurate sample selection, in order to remove from the sample those quasars whose observations may be "contaminated" (e.g. by gas absorption or dust reddening).
Recent results have shown that using spectrally-derived information from the UV side of the said relation, the observed dispersion goes below 0.18 dex in the average sample, and below 0.15 in the "cleanest" subsamples. With these uncertainties, about 10 quasars are needed to provide the same cosmological information as one SNIa. However, we have now hundreds of quasars at z>2. This is therefore equivalent to populating the distance-redshift diagram (the so-called "Hubble diagram") with tens of new SNIa at redshift up to 7. It has also been shown, by taking into account the effects contributing to the observed dispersion that cannot be removed through selection (inclination, variability, X-ray observational issues), that the intrinsic dispersion of the $L_X - L_{UV}$ relation is very low, possibly close to zero.

In my PhD project, I will deepen the understanding of the $L_X - L_{UV}$ relation, in order to (i) strengthen the evidence that quasars are standard candles, (ii) improve their implementation in cosmological analysis, (iii) better our knowledge of quasars emission mechanism.

As regard the first aim, I will further investigate the observed dispersion, implementing different fitting techniques in order to assure whether the aforementioned results are fitting-model depending or not. I will also deepen the analysis of those factors that are known to increase the observed dispersion but can not removed through sample selection. This analysis is necessary to strengthen the evidence that quasar are in fact standard candles, and that the observed residual dispersion is mainly due to these kind of effects and not to an intrinsic scatter of the $L_X - L_{UV}$ relation.

To improve the implementation of quasars as a cosmological probe, I will investigate possible tools for cosmographic fitting of the Hubble Diagram as, for example, Gaussian Processes (GP). Given the observational data, GP techniques allow to find a distribution of possible functions that are consistent with them, together with uncertainty information. These tools allow to perform non-parametric reconstructions of the Hubble Diagram, through which it is possible to test the consistency of the data with the standard cosmological model in a general, model independent way.

Finally, I will use spectral information to explore possible relations between spectral property of quasars, that can be used to better our understanding of the $L_{UV} - L_X$ relation and, more generally, of the physical link between the UV accretion disk and the X-ray Corona. This link is, in fact, still not completely understood; however, it must be very tight as the $L_X - L_{UV}$ relation has been proven to subsist for quasars with five decades in luminosity and at all redshifts, with what has been proven to be a very small dispersion. In the last decades many theoretical models have been proposed: most of them consider the energy transport mechanism from the disk to the Corona to be due to magnetic reconnection phenomena and/or they take extensions of the classical Shakura-Sunyaev accretion disk model into account in order to reproduce the observed parameters of the $L_X - L_{UV}$ relation. I will use the outcomes of the $L_X - L_{UV}$ relation analysis to test and constrain possible theoretical models.