A Phenomenological Model for QSOs

S. Nasiri\textsuperscript{1,2} & F. Tabatabaei\textsuperscript{1,3}

\textsuperscript{1} Institute for Advanced Studies in Basic Sciences, Zanjan, Iran
\textsuperscript{2} Department of Physics, Zanjan University, Zanjan, Iran
\textsuperscript{3} Department of Physics, Damghan University of Basic Sciences, Damghan.

ABSTRACT
A combined model on the basis of generalized FieldColgate and Terlevich Melnick models are proposed for QSOs. Using LBQS data, it seems that the predictions of the model is confirmed by observations. The behavior of comoving density versus redshift is consistent with LDDE for QSOs. Considering the cosmic evolution of SFR, a unified aspect for origin and evolution of QSOs and ordinary galaxies is implied by this model.

Key words: QSOs: formation, decay mechanism, QSOs: luminosity function – evolution galaxies: general.

1 INTRODUCTION
Since their discovery, different models have been proposed for explaining the observational properties, the origin and the evolution of QSOs. Among them, the remarkable models are: the standard model, Terlevich Melnick (TM) model\textsuperscript{[1,2,3]} and Field Colgate (FC) model \textsuperscript{[4]}. Besides the difficulties existing with each model, a considerable knowledge about the objects is established upon them. These models emphasize on two main points: a) the origin and evolution of QSOs and b) their inherent properties. Here we combine a generalized version of the FC model \textsuperscript{[5]} called GFC model with the TM model. Both of these are starburst models and have some conceptual features in common. The difficulties that an individual model are faced on, is removed for combined model. The byproducts of the resultant model are: a) the decay mechanism which is shown to be supported by observations using LBQS data\textsuperscript{[6]} the study of comoving density versus redshift satisfies the luminosity dependent density evolution (LDDE) for QSOs, c) a unified aspect for the origin and the evolution of QSOs and the ordinary galaxies is another implication of the combined model considering the cosmic evolution of the star formation rate (SFR) for these objects. In sec.2 we give a brief review of the existing models for QSOs. In sec.3 the combined model is described and sec.4 is ordered to observational investigation of evolution of QSOs and their correlation with galaxies. In sec.5 the concluding remarks are given.

2 A BRIEF REVIEW OF EXISTING MODELS
The early days of AGN research, produced a wide variety of remarkable models that were designed to explain the enormous amount of energy output of QSOs. However most of this models have failed in one way or another to explain for various QSO characteristics. Here we present a brief review of the most important models such as standard model, TM model and FC model. Most researchers agree that the energy source in QSOs is primarily gravitational and involves large concentrations of matter such as super massive stars or massive black holes\textsuperscript{[7,8,9]}. These has shifted the aim of theoretical and observational works towards the study of the properties of such objects and their environments. They have designed a model in base of accretion discs circling massive black holes. This model mass of the central black hole for a QSO with typical luminosity, \(10^{46}\) erg s\(^{-1}\) is assumed to be about \(10^6 M_\odot\). They also postulate the existence of small high density clouds very close to the nucleus where only broad permitted lines (BLR) are formed and a more extended system of low density filaments where narrow forbidden and permitted lines are formed (NLR). The line widths of the BLR (up to 10000 \(K m s^{-1}\) FWHM) are assumed to reflect the motions of the ensemble of cold \((T \sim 10^6 K)\) and dense \((n \sim 10^{23} cm^{-3})\) clouds moving in the gravitational field of the massive central object. The ionizing spectrum is assumed to follow a power law of the form \(f_\nu = \nu^{-1.0}\) up to a few hundred KeV. Other typical parameters of these clouds, also derived from the photoionization models \[10\](e.g. Collin-Souffrin 1990), are the ionization parameter \(U \sim 2 \times 10^{-3}\) and column density \(\sigma \sim 10^{23} cm^{-2}\).

While the black hole model for the QSO central engine is successful in accounting for many of the observed properties of the BLR of QSO, it remains unsatisfactory in that it requires a large number of arbitrary parameters which can not be predicted from theory and are freely adjusted to match the observations \[11\]. Meanwhile existing the accretion disk, the ubiquitous component of this model has not been proved through the polarization studies on both sides of the Lyman limit for intermediate-redshift QSOs observed by HST\[12\].
Another model which has not been definitively discredited is the model proposed by Terlevich and collaborators. The model is based on the nuclear starburst scenario. They assume that the observed activity of QSOs is the direct consequence of the evolution of a massive young cluster of coeval stars in the high metal abundance III regions of early-type galaxies [13]. In the other words, QSOs are postulated to be the evolutionary phase of elliptical galaxies. During this phase, most of the bolometric luminosity is emitted by the young stars, while the broad permitted emission lines and their variability are mainly due to rapidly evolving compact supernova remnants (SNR)[14]. Theoretical computations of the evolution of SNR in dense molecular clouds show that after sweeping up a small amount of gas and when their sizes are only few light weeks across, these remnants become strongly radiative. They deposit most of their kinetic energy in very short timescales, thus reaching very high luminosity. Because of the large shock velocities, most of the energy is radiated in the extreme UV and Xray region of the spectrum [15]. Terlevich et al studied the evolution of SNR in a high density medium \( n \sim 10^8 \text{cm}^{-3} \) the observed values of parameters of the BLR with density of the medium as the free parameter. But some problems exist with this starburst model. The rapid variability of the Xray radiation is not derived from this model. Further, the size of a typical QSO is assumed to be equal to the size of the core of a typical elliptical galaxy that have a radius of about 200Pc [13]. But imaging studies with HST show that AGNs remain unresolved at the highest currently attainable spatial resolution 0.05"[11].

Other astronomers not only do not consider the QSOs as an evolutionary phase of early type galaxies, but also consider them as an extreme case of galaxies with independent evolutions. According to this idea, Field and Colgate pronounced a starburst model, in which, galaxies and QSOs were different aspects of a same phenomenon. One generally believes that the galaxies, as separate units, are originated through some sort of gravitational instability. Moreover a fluctuation in density either developed in preexisted in the protogalaxies from which the galaxies were start to form. As a fluctuation grew in mass, it collapsed under the action of gravity, cooled and eventually a galaxy was formed. If one accepts that QSOs are extreme case of galaxies, one must seek for some characteristic physical parameters which are responsible for the observational differences of these objects with the galaxies. Field and Colgate [4] considered the angular velocity of protogalaxies as a characteristic parameter. The FC model assumes that the size of the galaxies, average mass of their constituent stars and their total energy output depend on the rotation rate of the protogalaxies or equally on the balance of the gravity with the centrifugal force at the end of the collapsing process. As an example assume two protogalaxies with the same initial masses and sizes, but one with an angular velocity ten times that of the other. The centrifugal force will then be hundred times weaker for the slowly rotating protogalaxy. Such an object will generate about 2.5 \( \times 10^3 \) times more energy than the extended one. According to the FC model, the compact and extended sources in the preceding example are the representatives for a QSO and an ordinary galaxy, respectively. While the FC model as a starburst model was able to describe energy problem and size of the QSOs, it could not explain most of their observed properties such as variability, their radio emission, unresolved images, the forbidden emission lines in the spectra and their intensity ratios. However, as mentioned before, the TM model, in spite of the fact that it could not satisfy the observed sizes of QSOs, was able to explain the other properties, satisfactorily. A claim which may arise here is the possibility of combining the FC and TM models as two starburst models, to reduce their individual problems. The authors recently have generalized the FC model by assuming the specific angular momentum (SAM) as the characteristic parameter for protogalaxies [5]. This quantity which mainly excludes the effect of the initial mass of the protogalaxies is assumed to be constant during the contraction procedure and is replaced by the angular velocity in the FC model. They called it generalized FC or GFC model and showed that the expected relation between the SAM and specific luminosity (SL) predicted by GFC model is satisfied by observations. They used the LEDA database for galaxies with different morphological types and showed as SL increases the SAM decreases. A by product of GFC model is the so called "decay mechanism" for QSOs. If we assumes that the QSOs are evolved from the slowly rotating protogalaxies, and therefore, posses much massive stars, one should accept that they must evolve faster than the ordinary galaxies as well. Thus, the QSOs formed in this way would have a half life proportional to the inverse square of their masses if presumably populated by the main sequence type of stars. They will evolve about \( 10^4 \) times faster than the correspondingly ordinary galaxies. The QSOs populated, on the average, by stars with the masses greater than eight solar mass, may eventually disappear from the contact with the rest of the universe as a result of collapse after consuming their energy sources. This process, if done, may lead to an evolutionary decay mechanism working for these objects in the course of time. We will examine this phenomenon in Sec.3 using observational data. In addition, using the same database, the plots of the number of compact (C) and the diffuse (D) galaxies versus their absolute magnitude shows that, as the object gets to be more and more compact becomes more and more luminous[5]. As outlined before, the dynamical aspects of the FC model is not capable of explaining some other observational properties of QSOs. The same weakness already exist for GFC. To remedy this problem will propose another model on the basis of GFC and TM considerations in the next section.

2.1 THE COMBINED MODEL

One may use the common features of the GFC and TM models, to obtain a new starburst model which includes the advantages and excludes the disadvantages of the previous models. In this respect, the following points are noteworthy: a) In the TM model, QSOs are considered as an evolutionary phase of elliptical galaxies, whereas, in the GFC model galaxies and QSOs are different manifestation of the same phenomenon that evolve independently biased by different initial conditions.

b) Either GFC or TM model, assumes the massive stars as
the source of the bolometric luminosity of QSOs. However, the BLR and NLR in the spectrum of the QSOs, their intensity ratios and variability could not be interpreted by GFC model. While in the TM model, their observational properties are explained by assuming SNR interacting with a relatively dense interstellar medium.

c) Although the TM model is successful in accounting for many of the observed properties of the BLR of QSOs, with only one free parameter, it is not capable of describing the small size of these objects. This is because of the considerations of QSOs as the core of elliptical galaxies with typical size ~ 200 pc (about hundred times more than observed values), in an evolutionary stage of the same galaxies. Whereas in the GFC model, the size difficulty does not exist. Here one can adjust the initial SAM of protogalaxies to arrive finally with the observed size of QSOs.

Therefore, it is seen that except for the initial considerations not only there is not a discrepancy between this two models, but also they complement each other. So it seems that a combined form of them may be more efficient model in explaining the observed properties of QSOs. Thus, one can assume, as mentioned before, the QSOs are eventually made from the protogalaxies with relatively low initial SAM compared with that of the protogalaxies which evolve finally to ordinary galaxies. Note that in the combined model two independent parameters, i.e. the SAM assumed by GFC model and the interstellar density conveniently chosen by TM model, determine the final state of the protogalaxy.

3 THE COMBINED MODEL AND PHENOMENOLOGICAL RESULTS

The observational implications of the combined model may be examined using the available complete surveys. Here we have used the Large Bright QSO survey (LBQS)[6] containing 1055 QSOs in the magnitude range of 16.0 < \( m_{\beta j} \) < 18.85 and redshift range of 0.2 < \( z \) < 3.4. The proposed combined model may have the following predictions,

1. Decay mechanism,
2. Galaxy QSO unification. In the following subsections we explain the above results separately.

3.1 DECAY MECHANISM

According to the combined model the QSOs must evolve faster than the ordinary galaxies. This is due to the high rate of energy production of their constituent massive stars. Therefore, one expects that the nearby QSOs must disappear from the contact of the rest of the universe by the known massive stars evolution scenario. Moreover, the disappearance must be most pronounced for luminous QSOs.

To check the above prediction one possible way is to consider the space distribution of QSOs. By considering the look back time effect on relatively distance objects such as QSOs, the above arguments lead to a nonuniform space distribution for them. In the other words, the plot of comoving number density versus redshift should reveal relatively more QSOs at far distances (i.e. at very long times ago). This is not satisfied by fig.1, that shows more or less uniform distribution for collective data of LBQS. To obtain the comoving density, we assumed \( H_0 = 75 \text{Kms}^{-1}\text{Mpc}^{-1} \) and \( q_0 = 0.0. \) However the discrepancy maybe removed by dividing the full range of magnitudes of a complete sample of QSOs into different luminosity groups. To do this, we have classified the data into 4 luminosity groups, where the absolute magnitude increases with increasing the order of groups. The group ranges are: (25.5, 23.0), (27.0, 25.5), (28.5, 27.0), (30,28.5). The corresponding distributions are plotted in figs. 2 to 5. As an overall view, it is clear from these figures that the decay mechanism exists and is more pronounced for the luminous quasars. The comoving density of QSOs associated with the 1st group, i.e. the dimmer QSOs are plotted in fig.2. They belong to redshift range of 0.2 < \( z < 0.93 \). It shows that, when we go to the redshifts higher than \( z = 0.2 \), the comoving density decreases so that after \( z \sim 0.93 \), no QSOs with this luminosity is seen. This may be due to seeing restrictions of these dimmer group of QSOs. Also it is seen that the decay rate goes rather slowly for this group. The situation is different for 2nd group (fig.3). The comoving density is distributed in the redshift range of 0.4 < \( z < 1.53 \), and nothing is observed in the redshift range of 0.2 < \( z < 0.4 \). The lack of observation of QSOs for 3rd group corresponding to 0.72 < \( z < 2.53 \) is enhanced and nothing is seen for \( z < 0.72 \). For the most luminous QSOs, i.e., the 4th group, decay mechanism has been going more rapidly. So that no QSOs is observed for \( z < 1.08 \). Note that, decreasing the comoving density of QSOs with increasing the group order for lower redshifts is not due to the instrumental and seeing limitations, because these kind of limitations become unimportant at high luminosities. The results obtained above, may be interpreted from the point of view of luminosity function of QSOs. For each group one can assume a distinct pure density evolution (PDE). However, the behavior of PDE is considerably different for different groups. Thus, for the collective LBQS data the luminosity dependent density evolution (LDDE) is more convenient.

3.2 QSOs AS EXTREME CASE OF GALAXIES

It is shown by Boyle and Terlevich that the cosmological evolution of star formation rate (SFR) of galaxies are almost
similar to the luminosity density evolution of QSOs[16]. Franceschini et al, recently have shown that the similarity between luminosity density of QSOs and SFR in elliptical galaxies are more remarkable[17]. Thus, it seems that there exist a relation between SFR and evolution of QSOs, indicating that a nuclear starburst is powering much of the QSOs luminosity as assumed in combined model. By the above arguments, one expects the evolution rate decreases from QSOs to elliptical galaxies and then to spirals. In the other words, QSOs evolve rapidly compared with the galaxies and among the galaxies, the ellipticals evolve faster than the spirals[5].

3.3 CONCLUDING REMARKS

The generalized form of FC model is combined with TM model to obtain a combined model for QSOs. The resultant model is capable of explaining the most observational properties of these objects such as energy production, size, BLR, NLR, variability, etc. The model assumes QSOs as evolved form of slowly rotating protogalaxies. A decay mechanism, acquired by this assumptions, is supported by LBQS data classified by different luminosity groups. On the other hand the ordinary galaxies are assumed to evolve from relatively rapidly rotating galaxies, which is a motivation for considering the QSOs as extreme case of galaxies. Thus in the framework of the combined model QSOs and the galaxies of different morphologies are considered to have the same origin with different initial conditions which affect their evolution rate at the later times. The investigation of behavior of the comoving density in terms of redshift for different luminosity groups supports the luminosity dependent density evolution for QSOs.
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