CHAPTER 1
Phenomenology of Active Galactic Nuclei

Introduction

The galaxies are considered as the building blocks of the universe in large-scale structure perspective. They are gravitationally bound systems consisting of a billion to a thousand billion stars and large amount of gas and dust. Largely our universe consists of so-called "normal galaxies", the luminosity of which is the sum of the luminosity of the constituent stars. In sharp contrast to these normal galaxies a small fraction (1-10 %) of galaxies are distinguished by their overwhelmingly bright impact nuclei, which emits copious amount of radiation. These highly luminous \( L_{\text{bol}} > 10^{42} \text{ erg/sec} \) galaxies are called as "active galaxies". As the radiation is emitted from the central compact and unresolved active nuclei \( r < 2 \times 10^{14} \text{ cm} \), Edelson et al., 1996), these galaxies are also known as "active Galactic Nuclei (AGNs)".

1 Characteristic Properties of AGNs

AGNs are the most powerful radiation emitters in the universe. The continuum radiation of AGNs extends over an extraordinarily broad range of frequencies from the highest energy \( \gamma \)-rays to the lowest energy radio waves. The spectra of these objects contain very broad and strong permitted and forbidden lines such as Ly\( \alpha \), NV, SiIV, CIV, CIII], MgII and Balmer lines. The equivalent widths (EW) of these lines suggest emission region velocities ranging upto 10,000 km/sec. The integrated line flux constitutes a significant percent of the total continuum flux. The AGNs exhibit rapid continuum and line flux variability, over a time scale of several hours in the \( \gamma \)-ray region. Their sizes \( r < c\Delta t \) turn out to be of the order of a few tens of astronomical unit, yet they emit radiation upto several hundred times the
mission from all the stars of a normal galaxy combined. The radiation of
GNs is mostly non-thermal and hence might be produced through physical
processes different from thermo-nuclear reactions that power the stars.

Thus the studies of AGNs may help in verifying and developing new
physical theories in extreme physics. The AGNs are considered as special
laboratories in which a large variety of unknown physical processes are
taking place. Currently, the near consensus view of AGNs is that they are
powered by the release of gravitational potential energy through accretion of
matter onto a Super Massive Black Hole (SMBH). However, the details of the
physical processes involved are still not completely understood. Therefore, we
do not yet have a comprehensive theory of AGNs that can predict the whole
range and variety of observed properties.

The simultaneous multi-frequency observations therefore have become
very much necessary to understand the energy generation mechanisms. It is
observed that x-ray emission is a common characteristic property of AGNs.
The x-ray radiation is considered to be produced by highly energetic particles
such as thermal plasmas at several million degrees temperature or
relativistic non-thermal plasmas, which might exist at the center of AGNs.
Much of the observed bolometric luminosity (= 10 %) in AGNs is radiated in
x-ray and γ - rays. The reproduction of this radiation by the circumnuclear
material causes much of the radiation in UV, optical and IR regions. The x-
ray spectrum (0.1 – 100 keV) of AGN’s can be well approximated by a single
power-law. The deviations from this power-law distribution are interpreted as
due to the effects of x-ray reprocessed by an accretion disk. A detailed study
of this reprocessed radiation yields direct physical information on the
geometry and the nature of the matter in the central nuclei of AGNs, which is
unresolved even by the largest telescope available today.
1.2 Observational Classification of Active Galaxies

A complete picture of AGNs can be obtained only by observing them simultaneously at all wavelength regions of the electromagnetic spectrum. The AGNs are classified arbitrarily into following types depending upon their appearance, luminosity, emission line properties and variability characteristics.

1.2.1 Seyfert Galaxies

Carl Seyfert in 1943 discovered a special class of spiral galaxies, which had bright "star like" nucleus containing strong and broad high excitation emission lines in their spectra, generally absent in normal galaxies. The emission lines had Doppler widths corresponding to velocities of several thousand km/sec. These galaxies are now known as "Seyfert Galaxies". The Seyfert galaxies constitute the lower luminosity end of the AGN phenomenon and have usually low redshifts.

Kachikian and Weedman (1974) identified two types of Seyfert galaxies on the basis of the widths of the nuclear emission lines. The first type, Seyfert 1 (Sy1) galaxies have very broad H\textsc{i}, H\textsc{e}I and H\textsc{e}II emission lines with Full Widths at Half Maximum (FWHM) of the order of 5,000 km/sec and above, while the forbidden lines like [OIII] (4959, 5007 Å), [NII] (6548, 6583 Å) and [SII] (6716, 6731 Å) typically have FWHM = 500 km/sec. On the other hand Seyfert 2 (Sy2) galaxies have both permitted and forbidden lines with approximately the same FWHM, typically 500 km/sec, similar to the FWHM of the forbidden lines in Sy1 galaxies.

1.2.2 Low Ionization Nuclear Emission Line Region (LINER) Galaxies

LINERs are the least luminous active galaxies in the AGN phenomenon. These galaxies are very common and are easily detected in
nearly 50% of all spiral galaxies (Ho et al., 1994). The non-stellar luminosity of most LINERs is small compared with the stellar continuum (Netzer et al., 1990). The strongest emission lines are of low ionization species and narrower (width ≈ 200-400 km/s) than the narrow lines of Seyfert galaxies.

Spectroscopically LINERs resemble Sy2 galaxies, except that the low-ionization lines like [O I] (3600 Å) and [NII] (6548, 6583 Å) are relatively strong. Some models indicate that the emission line spectra of LINERs are consistent with photoionization by a Seyfert like continuum, which is very dilute. However, the relationship between LINERs and AGNs is not completely understood.

1.2.3 Radio Galaxies

The galaxies with strong radio luminosity are called as radio galaxies. Powerful radio galaxies are usually associated with luminous elliptical galaxies, frequently with pronounced peculiarities and strong emission lines, whereas weak radio galaxies show weak or no emission lines. Radio maps of many of these objects show jets, a compact core with a flat spectrum that coincides with the nucleus of the galaxy and hot spots. Radio galaxies are spectroscopically classified into broad line radio galaxies (BLRGs) and narrow line radio galaxies (NLRGs). The BLRGs and NLRGs are the radio-loud and radio-quiet analogs of Sy1 and Sy2 galaxies respectively.

Fanaroff and Riley (1974) identified the two types of radio galaxies based on the radio morphology and the luminosity, which are now recognized as FRI and FRII radio galaxies. The FRIs are the lower luminosity lobe dominated radio sources. They exhibit very extended twin lobe structures. The lobes are connected by smooth and continuous double-sided jets. The FRII galaxies are more powerful radio lobe-dominated sources radiating
greater than $10^{35}$ W at centimeter wavelengths. This radiation emission occurs on kiloparsec size scales. The ends of these radio lobes are frequently edge-brightened and show bright knots of emission called “hot-spots” at their outer extremes. The jets of FRII galaxies are usually single sided or when double sided, one side is many times brighter than the other.

1.2.4 Quasars

Maarten Schmidt studied the optical spectra of the star like object 3C273. It was a continuous spectrum without dark absorption lines but had broad and strong emission lines. These lines were identified with the Balmer series and the ionized Magnesium with a redshift of 0.158 (Schmidt, 1963). Later on Schmidt and Jesse Greenstein identified the emission lines of the object 3C48, galaxy with a redshift of 0.36. The enormous luminosity of these radio-stars calculated based on the redshift distance implied that these objects were not truly “radio stars”, so the name “quasi-stellar radio-source” was coined by Greenstein to describe them (Greenstein and Mathews, 1963). Later on Hong-Yee Chill gave the short form “quasar” for quasi-stellar radio source. Today quasars are regarded as the most luminous objects in the universe. The quasars are characterized by their unresolved nuclei, time variable nonthermal continuum, broad and strong emission line with large redshifts.

Another recently recognized important characteristic property of quasars is that they have approximately similar broad Spectral Energy Distribution (SED) spread across seven orders of magnitude in frequency. Based on the radio luminosity, the quasars are subdivided into radio-loud (RL) and radio-quiet (RQ) quasars. The radio emission in quasars is associated with a jet of relativistic electrons. Both RQ and RL quasars have relatively steep IR through optical continuum emission. The continuum flux declines towards shorter wavelengths and has superimposed broad emission
The IR through optical continuum of RQ quasars follows roughly a power law form—a straight line with negative slope on plot of log \( F \) versus log \( v \). Some quasars show an excess continuum emission in the blue to UV part of the spectrum and is called as "Big Blue Bump" (BBB). The BBB component is attributed to the thermal emission from a hot accretion disk of temperatures around 30,000 K surrounding a super massive black hole. Some astronomers argue that it might be due to free-free emission.

Though the quasar flux decline from UV to x-ray, some quasars show excess x-ray emission. Quasars show continuum and line flux variability on timescales of several days in the optical to several minutes in x-ray. The physical origin of these variabilities is not well understood.

### 1.2.5 Blazars

The word 'blazar' was coined by Spiegel E in a banquet speech at the Pittsburgh meeting on BL Lacertae (BL Lac) objects (Wolfe, 1978). The characteristic properties of blazars are—strong optical polarization, violent variability, a compact flat spectrum radio source and a very smooth continuum spectrum. Among the brightest RL quasars, a few exhibit high polarization and violent variability in optical region, which have fairly featureless continuum spectra. These objects are called as optically violent variable (OVV) quasars. BL Lac objects, high polarization quasars and OVV's are combinedly called as blazars. Since the BL Lacs indicate no sign of host galaxies, it was thought some time that these objects might be the extreme case of AGN phenomenon. The continuum radiation of BL Lacs is Doppler boosted due to orientation of the relativistic jet close to our line of sight (9 ≈ 10'). BL Lacs are distinguished by the absence of strong emission or absorption lines in their spectra.
1.2.6 Star Burst Galaxies

A significant fraction of galaxies show the signatures of recent large-scale star formation activity. Such galaxies are widely known as starburst galaxies. It has been estimated from the study of Hα flux in interacting galaxies, that the star formation rate is ≈ 6 times higher than the normal galaxies (Bushouse, 1987). A general feature is that star formation is more concentrated towards the center (Hummel, 1981). Huge star bursts are found towards the nuclei of star burst galaxies (Kennicut et al. 1986; Bushouse, 1987). In star burst galaxies, unlike quasars and Seyferts, BLR is absent for the emission lines. No part of the continuum is variable, so there is no evidence for relativistic beaming effects. UV continuum shows absorption lines, characteristic of hot and massive stars. This gives the evidence that the formation and death of hot stars (O and B type) is taking place in great number and thus releasing enormous amount of radiation. The relationship between AGNs and nuclear starbursts is not clear.

1.2.7 Ultraluminous Far-Infrared Galaxies

The Infrared Astronomical Satellite (IRAS) has discovered a highly luminous class of infrared galaxies, which emit over 90% of their total energy in the far infrared (FIR) region (Soifer et al., 1987). The IRAS has for the first time detected these galaxies at wavelengths 12, 25, 60 and 100 micrometers. Most of the radiation emitted by these galaxies is believed to be due to re-radiation from dust (at T ≈ 100 K or less), which is heated by massive star formation (starburst activity) or by a hidden AGN, which we cannot observe through the dust. These galaxies have their FIR luminosities \( \geq 10^{12} L_\odot \) and exceed optical luminosity by a factor of 10 or more. Many FIR galaxies of IRAS are starburst galaxies. Therefore, these galaxies have become key targets to study the relationship between galaxy interactions,
enhanced circum-nuclear star formation and also to investigate the creation of massive black holes in their nuclei as the end product of the starburst activity (Heckman, 1990; Norman and Scoville, 1988).

1.3 The Structure of AGNs (AGN Paradigm)

The fundamental question about AGNs is how the enormous amount of energy that is detected as radiation is generated. To understand the energetics of AGNs, it becomes very much essential to understand the general structure of AGNs. The current paradigm of working model for the AGN phenomenon is a central engine that consists of a hot accretion disk surrounding a supermassive black hole. The energy is generated by gravitational in-fall of material, which is heated to high temperatures in a dissipative accretion disk. The widely accepted approximate structure of AGNs based on the multi-wavelength studies (Krolik and Begelman, 1986; Blandford and Rees, 1978) and certain theoretical considerations (Rees, 1984) is described below.

1.3.1 Super massive Black Hole:

The most efficient way to obtain sustained release of large bolometric luminosity (upto $10^{46}$ erg/sec) from the compact nuclei of AGNs is by the extraction of gravitational energy from the accretion of matter on to a black hole (Rees, 1984). Other mechanisms such as starburst activity (Terlevich et al., 1992) are also offered for the AGN phenomenon. In the popular black hole paradigm for AGN phenomenon, the multiwavelength continuum is thought to arise from non-thermal emission processes occurring close to the super massive black hole.

A direct observational evidence for the presence of super massive black hole is difficult with the present day telescopes. Even the Hubble Space Telescope (HST) cannot image the accretion disk, as the size of the region is $< 0.1$ pc.
for a $10^8 M_{\odot}$ SMBH. The continuum x-ray emission originates around the region of this super massive black hole and illuminates optically thick but geometrically thin accretion disk situated at a few milliparsec from the center. This interaction gives rise to a Compton reflected spectrum and many strong emission lines. Therefore, we must rely on indirect observational evidence for the presence of black holes as well as to estimate its mass. The recent HST observations have revealed that super massive black holes having masses in the range $10^6-10^9 M_{\odot}$ are ubiquitous in the universe. Almost all the galaxies harbor black holes in their centers and matter accretion rate is crucial in making a galaxy either active or non-active. The observations of the parsec scale disk in the center of the nearby M87 AGN with the Faint Object Spectrograph onboard the HST telescope has shown that the gas was rotating in a Keplerian orbit about a central SMBH of mass $= 2 \times 10^9 M_{\odot}$ (Macchetto et al., 1997).

The masses of super massive black holes correlate almost perfectly with the velocity dispersions of their host bulges and the relation is much tighter than the relation between the black hole masses and the bulge luminosity (Ferrarese and Merritt, 2000). Thus there are many strong arguments in favor of the SMBH as against the best alternatives of AGNs being powered by starbursts (Terlevich and Melnick, 1985; Heckman et al., 1991; Filipenko, 1992). However, it looks plausible in case of some radio-quiet AGNs to be partly powered by starburst phenomenon.

### 1.3.2 Accretion Disks:

The accretion of matter onto a super massive black hole is considered as the basic physical process to generate very high energy in AGNs. The rotating disk of matter surrounding the SMBH is called as the accretion disk. The detailed structure of the accretion disk depends on a variety of parameters such as the magnetic field strength, the accretion rate and the presence or absence of a disk corona or jets. The nature of viscosity and the
role of thermal instabilities are not well understood. However Blandford (1985) and Begelman (1985) have provided the basic structure of accretion disks that are consistent in explaining some of the observational results.

The gravitational field of the SMBH will attract the gas clouds in the central parsec region. These accelerated gas clouds lose their kinetic energy, which is transformed into frictional heating. In these processes the accretion disk is differentially heated. The frictional interactions of gas clouds in the accretion disk transfer the angular momentum and dissipate binding energy as radiation (Shakura and Sunyaev, 1973; Novikov and Thorne, 1973; Pringle, 1981; Rees, 1984; Blandford, 1990).

For a disk surrounding a typical black hole of mass $10^8 M_{\odot}$ that is accreting at the Eddington rate the emission from the inner part of the disk is maximized at $v = 3.6 \times 10^{16}$ Hz, which corresponds to photon energy of $\approx 100$ eV. This lies in the extreme UV or soft x-ray region of the EM spectrum (Peterson, 1997). Thus the prominent continuum emission in UV-optical and the big blue bump component observed in Sy1 galaxies and quasars are considered as the signatures of the accretion disk.

At very low accretion rates ($M^*/M^*_{\text{E}} < 0.1$), the disk becomes optically thin and a two-temperature structure is possible. At high accretion rates, $M^*/M^*_{\text{E}} \gg 1$, the upward flowing radiation is partially trapped by the accreting material and the disk expands vertically into a radiation torus or thick disk, which radiates inefficiently. As the heat transport in the radial direction is non-negligible, the emitted spectrum is close to a single temperature blackbody spectrum at temperature $T \approx 10^4$ K.

1.3.3 The Emission Line Regions:

The strong and broad emission lines of AGNs are one of the most interesting properties of AGNs. The spectra of AGNs can be broadly divided
into two classes such as broad lines and narrow lines depending upon the line-widths. The broad lines have typical widths corresponding to a velocity of about 10,000 Km/sec and the narrow lines have about 1000 km/sec. These lines are emitted from two physically distinct regions surrounding the central accretion disk. Accordingly these regions are called as broad line region (BLR) and narrow line regions (NLR). The BLR reprocesses the continuum radiation of central source by ionizing it at UV energies that cannot be observed directly. The studies of strong emission lines thus provide indirect information about the nature of continuum radiation. The photo-ionization of continuum radiation due to which strong broad and narrow emission lines are emitted occur within the central kiloparsec scale of the active galactic nuclei (Davidson and Netzer, 1979; Netzer and Maoz, 1990).

The broad line variability observed in AGNs suggests that the size of the BLR is ≈ 10-100 days in Sy1 galaxies and up to a few light years in bright quasars (Netzer, 1990). The absence of strong, broad forbidden lines such as 4363 Å, 4959 Å and 5007 Å lines of [OIII] indicates that the electron density is ≈ 10^8 cm⁻³. The critical density for collisional de-excitation of the \(^{1}\)S₀ in OIII ion is ≈ 10^8 cm⁻³ and thus provides a lower limit for the electron density in the BLR region. The only forbidden line observed in UV/Optical spectra is the inter-combination line CIII] 1909 Å which has a critical density of ≈ 10^{10} cm⁻³. Thus the presence of the CIII] 1909 emission line in AGN spectra has been used to establish an upper limit to the electron density (≈ 10^{10} cm⁻³) in the BLR region (Peterson, 1997).

The NLR in AGNs is relatively less interesting region than compared to the BLR. The NLR is the largest spatial scale (10-100 pc) where the ionizing radiation from the central source dominates over the other sources. NLR is spatially resolved in the optical region from the ground-based telescopes. A wide variety of ionization states are present in the spectra of NLR. The
electron densities in NLR are generally believed to lie in the range of $10^2 - 10^4$ cm$^{-3}$, which is established from the observation of [SII] and [OIII] lines. The range of electron temperatures ($T_e$) measured for the NLR is about 10,000 - 25,000K with a typical value of $T_e = 16,000$ K (Koski, 1978). Thus it should be noted that a broad range of densities and temperatures characterizes the NLR. The mass estimation of NLR is achieved by using luminosity of narrow emission lines. The mass of the ionized hydrogen gas comes out to be $\sim 10^9$ $M_{\odot}$. In the case of FIR emitting AGNs, including the radio-quiet quasars, Seyferts and starburst galaxies, there is an excess mass of $10^{10}$ $M_{\odot}$ of gas just outside the NLR region called the Extended Narrow Line Region (ENLR) and extends up to $\approx 20$ Kpc from the nucleus. Currently the ENLR is believed to be the ambient gas of the accretion.

1.3.4 Molecular Torus Ring:

A major breakthrough occurred when Antonucci and Miller (1985) found that the polarization spectra of some Sy2 galaxies such as NGC1068 and 3C 324 (Antonucci, 1984) contained broad emission lines like those seen in Sy1 galaxies. These observations were attributed to the presence of a thick disk or torus of obscuring material surrounding the central engine between BLR and NLR regions. A torus of dense obscuring gas and dust with molecular gas is believed to be the composition of molecular torus ring. The observations of NGC 1068 (Antonucci and Miller, 1985) and radio galaxy 3C234 (Antonucci, 1984) are presently considered as the best examples to support the existence of obscuring torus ring. A mass of about $10^9$ $M_{\odot}$ molecular gas is estimated to be present in the inner kiloparsec of NGC1068 (Ian Robson, 1996).

1.3.5 Jets and Superluminal motions:

The radio morphology of quasars and radio galaxies are often described broadly in terms "compact" (i.e. unresolved at 1" resolution) and
"extended" (i.e. spatially resolved) components that have different spectral characteristics. The extended radio morphology has two 'lobes' of radio emission more or less symmetrically located on either side of the central optical nuclei. The linear extent of the extended lobes is as large as several megaparsec (Mpc). These highly collimated twin lobes of radio emission are called jets. Martin Rees (Rees, 1971) proposed the idea that the radio lobes were continuously fueled along the channels by the central engine. The jets in AGNs are beams of relativistic plasma, which transport particles and energy to the extended radio lobes from the central engine. The jet emission is synchrotron radiation (Schwinger, 1948) emitted by the charged particles such as electrons that are gyrating at relativistic speeds around magnetic field lines (Shklovsky, 1958). The extended component of radio galaxies is optically thin to its own synchrotron emission whereas it is not so in the case of compact component. Recently spectacular jets have been observed in M87 and NGC 4261 by the HST (Ian Robson, 1996).

The narrow parsec scale jets detected by VLBI techniques and their subsequent observations led to the discovery of superluminal motion phenomenon in which jets appear to travel outwards from the nucleus with apparent velocities as high as 10 times the speed of light. The relativistic effects can explain the lack of counter jets for superluminal and other radio sources. The approaching jet, which is oriented toward the line of sight, is significantly enhanced in its brightness and is called as 'Doppler boosting'. The receding jet is correspondingly dimmed to such an extent that it often remains invisible on the deepest radio maps.

1.4. Physical Processes of Continuum Radiation in AGNs

The continuum radiation emitted by AGNs extends over an extra ordinarily broad range of frequencies from the highest energy γ-rays to the lowest energy radio waves. The continuum spectrum has an overall complex shape that can be approximated by a simple power law ($f \propto \nu^n$) form over
fairly wide wavelength intervals. The power law continuum has superimposed excess emission components such as soft x-ray excess, big blue bump (BBB) and IR bumps, the physical origin of which is not well understood. The continuum radiation is produced in elementary processes like synchrotron emission, bremsstrah lung, pair production and thermal processes. This radiation is further modified by scattering, absorption and re-emission processes in the BLR region. A brief but adequate discussion of all the radiation processes is given in the following section.

1.4.1 Thermal Radiation:

The thermal radiation emitted by a solid body is described by an ideal concept of a blackbody. A blackbody is a solid body and is ideally in thermal equilibrium at a temperature \( T \) K with its surroundings. A blackbody is a perfect absorber as well as an emitter of radiation at all frequencies. The emission from a blackbody is extremely difficult to build in a laboratory, but stars and accretion disks in AGNs can be reasonably considered as approximate blackbodies. The blackbody spectrum is well described by Planck's law (Planck, 1901), which is based on the quantum theory of electro-magnetic radiation. The blackbody radiation is isotropic and unpolarised. The BBB component of the UV/Optical spectra of AGNs is attributed to thermal emission from a hot accretion disk at temperature \( 10^5 \) K. The origin of the BBB, whether from an optically thin or optically thick disk is not clearly understood.

1.4.2 Thermal Bremsstrahlung:

When an electron is accelerated by the electric field of a positively charged ion, it emits a continuum radiation known as thermal bremsstrahlung or free-free radiation. The free-free emission is typical of an
optically thin gas, however at longer wavelengths the emission becomes optically thick and self-absorbed. The free-free emission is mostly observed in ionized hydrogen surrounding hot stars. These regions are referred to as HII regions. A typical free-free emission spectrum extends from optical to radio wavelengths depending on the density of the gas. The long wavelength turn over corresponds to the wavelength at which the medium becomes optically thick to the radiation. The radiation is then self-absorbed at longer wavelengths. The self-absorption is a key feature of the emission mechanisms in AGNs.

1.4.3 Synchrotron Radiation:

Synchrotron radiation is a common feature of high-energy astrophysics and denotes the presence of relativistic electrons and a magnetic field. Synchrotron radiation is emitted when a relativistic electron is accelerated by a magnetic field and for this reason it is sometimes called as magnetic bremsstrahlung. Synchrotron radiation was first suggested by Alfvén and Herlofson (1950) and independently by Shklovsky (1953) to account for the radio-emission from supernova remnants and AGNs. It is now widely accepted that the radio emission from radio galaxies and radio quasars is synchrotron radiation. The radio emission from jets and lobes is also explained by synchrotron mechanism. Synchrotron radiation is continuous and highly polarized. At very high frequencies synchrotron radiation becomes self-absorbed.

1.4.4 Compton and Inverse Compton processes:

The Compton effect is observed when a high-energy photon interacts with a stationary electron. In this interaction the electron energy is increased thereby decreasing the photon energy. The interaction is often
referred to as Compton scattering. The low energy case of Compton scattering is termed as Thomson scattering. Compton emission becomes significant in regions where electrons are immersed in an intense high-energy photon field. The accretion disks of black holes provide ideal condition for Compton scattering, which acts as a cooling process for the high-energy photons.

The interaction of a high-energy electron with a photon, thereby boosting the photon energy at the expense of the energy of the electron is called as "Inverse Compton" (IC) scattering. Thus IC emission plays the role of a source of energy for photons and a cooling process for the high-energy electrons. Inverse Compton process is considered as the electric analogue of the synchrotron process. The production of x-ray and gamma ray photons in AGNs is attributed to IC emission.

1.4.5 Pair production:

The pair production process is a high-energy process and becomes important in the central regions of AGNs where very high-energy photon densities are known to be present. Pair production is the production of an electron-positron pairs due to the interaction between two high-energy $\gamma$-ray photons. High-energy gamma rays in the central disk of AGNs may be produced due to the Inverse Compton scattering of soft photons by highly relativistic electrons. Pairs can also be produced when the temperature of a plasma become relativistic (Krolik, 1999). The pair production process consists of a very high-energy photon, interacting with the field of a nucleus or another photon and being converted into an electron-positron pair. It is a spectacular source of particles and a dramatic sink for the radiation field.
1.5 Objectives of the Thesis

The observational classifications of AGNs provided in section 1.2 indicate that AGN activity spread over several orders of magnitude in luminosity and redshift. The wide range and observed diversity of spectral properties of different classes makes it much more difficult to build a comprehensive model for AGNs. This fact prompts one to consider different physical processes in these AGNs. With the availability of better sensitivity and high-resolution data from space and ground based telescopes it has now become possible to unify at least some subclasses of AGNs. Observationally there appears to be a phenomenon of dichotomy in several subclasses of AGNs such as Sy1 and Sy2 galaxies; FRI and FRII radio galaxies; OVV's and BL Lac objects etc. The spectroscopic studies of Sy 1 galaxies and quasars in Optical, IR and x-ray regions have shown similar line and continuum characteristics. Thus it becomes interesting to investigate whether these two class of objects show similar or otherwise spectral properties at UV wavelengths. Strong line and continuum luminosity correlations in Seyfert galaxies were first observed by Baldwin (1978). The Sy1 galaxies are low redshift and low luminosity AGNs while quasars are the highest luminosity AGNs with wide ranging redshifts. The spectra of both types contain broad emission lines such as Lyα, NV, CIV, SiIV and MgII lines with similar widths. The physical origin of these different spectral properties is not well understood. A longstanding fundamental question relating Sy1 galaxies and quasars is why do these active galactic nuclei which differ in absolute luminosity by a factor up to 10^4 have in first approximation similar line profiles, line widths and line intensity ratios.

Thus the availability of large UV spectroscopic data of Sy1 galaxies and quasars obtained by International Ultraviolet (IUE) satellite motivated us to undertake a detailed spectral studies of these two kinds of objects to
understand the line and continuum correlation properties. There were no UV spectroscopic observations of Sy1 galaxies and quasars for such large number of AGNs available prior to the launch of IUE satellite in 1978. Thus IUE provided a new and unique set of UV spectroscopic homogeneous data for the first time in the history of AGNs and is expected to provide new information on line and continuum luminosity dependences and the physical processes taking place close to the central engine which drive these most luminous objects.

Therefore, I have obtained a large sample of spectral data of Seyfert 1 galaxies and Q quasars from the Vainu Bappu observatory Data Center, Kevlar that was installed at this center by K K Ghosh. Some of the spectra that I have used in my thesis have been studied by several other groups, important among them are Chi Chao Wu et al. (1983), Wamsteker et al. (1986), Kinney A L et al. (1987), Busan et al. (1990) and Gondhalekar P M (1990). Chi-Chao Wu et al. (1983) who have studied only about 20 Sy 1 galaxies and find a correlation between CIV luminosity and 1450 Å continuum. Similarly Wamsteker et al. (1986) have studied CIV luminosity with 1350 Å. Kinney A L et al. (1987) have found Lyα and CIV luminosity correlation with 1450 Å continuum in 21 intermediate redshift quasars. Busan et al. (1990) have carried out line profile symmetry and line-continuum correlation studies in 10 low redshift AGNs. They have found line profile similarity in Lyα and CIV lines. Gondhalekar P M (1990) has studied the Lyα and CIV line variability in 34 quasars. He has discovered that the BLR size does not scale with the luminosity of the nucleus.

The above-referred investigations using IUE data have studied only few aspects of the UV properties of AGNs, particularly of Sy1 galaxies and quasars. They have used a small sample of AGNs covering narrow range of luminosity and redshift. Therefore I have taken spectra of large sample of
Sy1 galaxies and quasars (96 objects) covering wide range in luminosity and redshift to obtain statistically significant correlations. The data collected by me is from the observations made over 13 years. I have undertaken a detailed analysis of this large sample of spectral data adopting a uniform methodology in line and continuum flux measurements. The galactic extinction correction applied to the spectra and fitting 'deblend'ed gaussian profiles to the emission lines are the special features of my investigations. The major focus of my research is towards understanding the line and continuum luminosity correlations in the UV spectra of Sy1 galaxies and quasars. The broad objectives of my investigations are as follows:

1) To measure the Equivalent Width (EW) and line fluxes of strong emission lines such as Lyα, NV, SiIV, OIV], CIII] and MgII in Sy1 galaxies and Quasars.

2) To study the dependence of EW and fluxes of strong emission lines with the UV continuum and the redshift.

3) To study the dependence of UV line fluxes with the continuum fluxes at other wavelength regions available in the literature to explore the possible correlation between UV properties and properties at other wavelength regions.

4) To study the dependence of line flux ratios with the redshift.

5) To study the correlation between line and continuum flux variability.

6) To study the multifrequency SED distributions.

The results of my investigations and the final conclusions are presented in Chapter 6.