ACTIVE GALACTIC NUCLEI

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Content

1. Historical aspects
1.1. Prehistory
1.2. After the Discovery of Quasars
1.3. Accretion Onto Supermassive Black Holes: Why It Works So Well?
2. The emission properties of radio-quiet quasars and AGN
2.1. The Broad Band Spectrum: The “Accretion Emission"
2.2. Optical, Ultraviolet, and X-Ray Emission Lines
2.3. Ultraviolet and X-Ray Absorption Lines: The Wind
2.4. Variability
3. Related objects and Unification Scheme
3.1. The “zoo" of AGN
3.2. The “Line of View" Unification: Radio Galaxies and Radio-Loud Quasars, Blazars, Seyfert 1 and 2
3.3. Towards Unification of Radio-Loud and Radio-Quiet Objects?
3.4. The “Accretion Rate" Unification: Low and High Luminosity AGN
4. Evolution of black holes
4.1. Supermassive Black Holes in Quasars and AGN
4.2. Supermassive Black Holes in Quiescent Galaxies
5. Linking the growth of black holes to galaxy evolution
6. Conclusions
Acknowledgements
Glossary
Bibliography
Biographical Sketches

Summary

We recall the discovery of quasars and the long time it took (about 15 years) to build a theoretical framework for these objects, as well as for their local less luminous counterparts, Active Galactic Nuclei (AGN). They all harbor a supermassive black hole accreting gas from its environment. The infalling gas forms an “accretion disk" around a black hole and radiates a fraction of its rest-mass energy. It gives rise to a broad-band spectrum due to thermal processes, extending from the far-infrared to the hard X-ray range. There are indications that the X-ray emission is produced very close to the black hole (at a few gravitational radii), and that the disk extends also quite close. Some AGN

and quasars are characterized by an intense radio emission, and are therefore called “radio-loud". The radio emission is due to the synchrotron process from a relativistic jet. It is always accompanied by an intense non-thermal gamma-ray emission. AGN take different aspects according to the angle between the line of sight and the jet (or the rotation) axis. When the jet is directed towards us, the non-thermal emission is relativistically amplified and the object appears as a “blazar", strongly variable and emitting very high energy gamma-rays. More generally the “Unified Scheme" invokes the direction of the line of sight to account for the differences between several classes of AGN: close to the plane of the accretion disk, a thick “dusty torus" blocks the radiation from central regions, like the UV continuum and the broad spectral lines. As an example, powerful radio-galaxies are radio-loud quasars seen at such orientation.

Supermassive black holes span a range of masses from 10^5 to 10^{10} solar masses and are probably present into all galactic nuclei, but with different levels of activity. Only one percent of them are luminous AGN, and in about 40% galaxies, the central black hole accretes gas at a very low rate. The accretion flow has then a quite different structure from that of luminous AGN, and it seems to be always accompanied by a jet. The mass of the central black hole correlates with the mass of the spheroidal part of the galaxy, most developed in early type (elliptical) galaxies. The formation and the evolution of supermassive black holes are thus tightly linked with the evolution of the galaxies themselves.

1. Historical Aspects

1.1. Prehistory

When Marteen Schmidt working at the five meters telescope on Mount Palomar took the spectrum of a faint blue “star", whose position coincided exactly with that of a recently discovered radio-source having the number 273 in the third Cambridge catalogue (thus 3C 273), he certainly did not think he would do a major discovery in extragalactic research. He observed in this spectrum several bright and broad spectral lines located at unfamiliar wavelengths. However, he noticed a regularity in the positions of the four lines: they seemed to be separated in the same way as Balmer series of hydrogen lines, although all of them were strangely shifted by 16% towards the red. “What if they are indeed Balmer lines?” he wondered. The required redshift corresponded to a velocity of 16% of the speed of light, if it was caused by the Doppler effect. If so, the star was not a star in our Galaxy but a very distant object participating in the expansion of the Universe! He consulted his colleagues and an additional test of the hypothesis was performed. An observation was made in the infrared to check whether one more hydrogen line was there, and it was there, shifted by the same amount! This was reminding of another faint blue star located at the position of the radio source 3C 48, whose spectrum revealed in 1960 intense broad and bright lines also at completely unknown wavelengths (this result was not published at this time). They were thus immediately also identified with the Balmer series and other lines observed in planetary nebulae, this time “redshifted" by 37%.

Except for another radio-source corresponding to a very distant cluster of galaxies, 3C 295, such high redshifts were never observed before. But the two blue “radio stars" were not resembling in any way a galaxy cluster. Nevertheless, it was rapidly admitted by many specialists that their redshifts were indeed “cosmological", i.e. due to the Hubble expansion law, and therefore that “quasars", first baptized “quasi stellar radio sources" (*The fact that they are “stellar-like" means that their size is smaller than the resolution given by the atmospheric turbulence, close to one arc second.*), were distant by more than a billion light-years and had a luminosity in the visible range (i.e. a radiated power) on the order of 10^{39} Watts. So they were brighter than a thousand galaxies altogether. But it was also discovered that 3C273 was variable in a time scale of a week. According to the causality principle, it means that its size should be smaller than a light-week, i.e. a millionth of a galaxy diameter, otherwise the different parts of the source could not communicate in order to establish a common variability pattern, and variations would be smeared by the time it takes the light to cross the object. Finally, they were relatively common objects, as hundreds of similar ones were discovered in a few years and tens of thousands are known now, some of them being distant by more than 13 billion light-years (*Actually their light has traveled during 13 millions years, but their real distance is much larger than 13 millions light years, according to the expansion of Universe.*), their light reaching us after a travel lasting almost as long as the age of the Universe.

All this raised very difficult problems, and some people argued that the cosmological interpretation of the redshift was wrong, and that it was necessary to invoke a still unknown physical law to explain the redshifts. This started the “redshift controversy" which lasted for about 15 years beginning in 1965 and occupied a large fraction of the meetings during all this time. The discoveries concerning quasars were indeed so unprecedented and not immediately understandable, that they permanently provoked hard debates and created the idea that something else other than the known physical laws was at work. The cosmological origin of their redshift is now well established, because quasars are observed in clusters of galaxies whose redshifts are well-known, and because galaxies with known and relatively high redshifts are located on the line of sight between us and quasars and produce imprints in their spectrum. Finally, high quality observations made by the Hubble Space Telescope allowed us to see host galaxies harboring the nearest quasars.

The discovery of quasars could have been anticipated and actually *was* anticipated in the 1950s by Geoffrey Burbidge, but very few people realized at this time the importance of his assessments. A new science was developed when radars built during World War II were pointed towards the sky: radio-astronomy. It revealed intense sources of radio light whose origin was soon attributed to synchrotron radiation. These electromagnetic waves are emitted when highly relativistic charged particles - mainly electrons - are moving in a magnetic field. In 1954 two of the most intense radio-sources were identified by Baade and Minkowski with M87 (the largest galaxy of the Virgo cluster, called also Virgo A) and with Cygnus A (Figure 1), a faint distant galaxy seeming to be made of two galaxies in collision (this is a very important aspect of the story, as we shall see later). So these sources appeared about 1000 times more luminous in the radio range compared to other galaxies like the Milky Way for instance.

Since the intensity of synchrotron radiation depends on the energy density of the particles and on that of the magnetic field, Burbidge made the assumption that these quantities were equal and he obtained the total energy of the system (it corresponds actually to a minimization of the total energy). The result was that 10^{54-55} Joules was stocked in extragalactic radio-sources, corresponding to the complete transformation of $10^{7-8}\ M_{\odot}$ into pure energy. Burbidge thus raised immediately the question of the origin of this enormous energy. His result was largely premonitory since only thirty years later, in 1990, it was recognized that radio-galaxies and quasars have the same central engine, and moreover that powerful radio-galaxies are radio quasars seen at a different view angle.

Another birth of the subject can be dated to the study of six peculiar galaxies by Carl Seyfert in 1943 (Figure 2). These galaxies are characterized by bright stellar-like nuclei, with blue color and broad bright lines in its spectra. Seyfert attributed the widths of the lines to Doppler effect caused by the motions with randomly oriented velocities as high as 8500 km s^{-1}. Later, these six galaxies, as well as many other similar galaxies, were called “Seyfert galaxies".

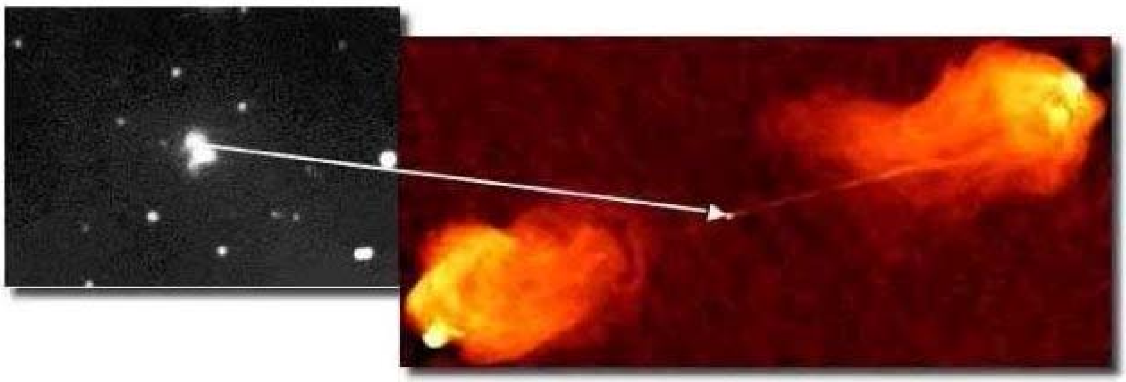

Figure 1. The radiogalaxy Cygnus A. On the left, a visible image as it was observed by Baade and Minkowski in 1954. On the right, a recent radio map of the galaxy, showing two big lobes linked to the galaxy (which is in the center) by a thin jet. Notice the "hot spots" at the extremities of the radio lobes. Source: NRAO.

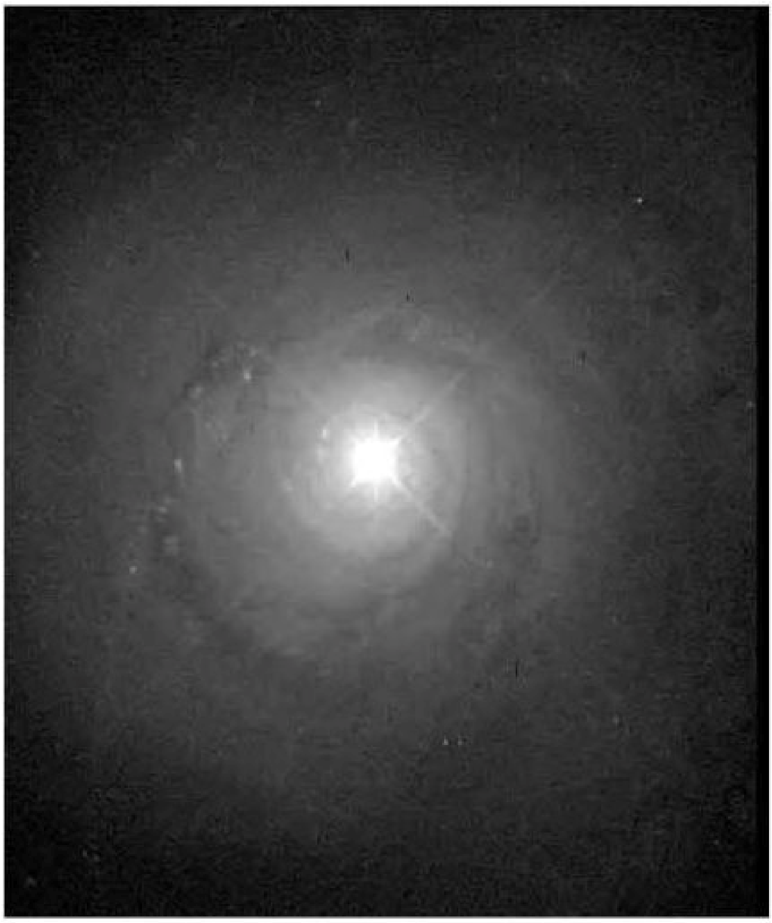

Figure 2. An image of one of the six galaxies studied by Seyfert, NGC 5548, obtained with the Hubble telescope. It shows the bright and starlike nucleus. Source: HST.

The article by Seyfert was referred for the first time sixteen years later - in 1959 – in two papers published in the same issue of the Astrophysical Journal, the first one by Margaret and Geoffrey Burbidge, with Kevin Prendergast, and the second by Lodewijk Woltjer. The Burbidges and Prendergast concluded from a study of the rotation curve based on the stellar velocities that the gas in the nucleus of the Seyfert galaxy NGC 1068 had too large velocity to be kept in by the strength of the gravity, and it should be ejected from the nucleus. On the contrary, Woltjer concluded from a discussion of the properties of *all* six Seyfert galaxies that the gas should be gravitationally confined by a very massive body of a billion solar masses. Both were right: at present we know that there is a large compact mass — a black hole — in the nucleus of every Seyfert galaxy, but we also know that the gas emitting some of the spectral lines is indeed outflowing. This discussion was probably the departure point and a part of the more general redshift controversy.

1.2. After the Discovery of Quasars

Immediately after the discovery of quasars, their similarities with some local objects appeared evident. The most obvious analogues were Seyfert nuclei. In a sense it was a premonitory idea since, at this time, Seyfert nuclei did share with quasars only their small size, their blue color, and their broad and intense emission lines. Quasars are about two orders of magnitude more luminous than Seyfert nuclei, and one did not know that their broad band spectra and their variability properties, in short all their properties, were exactly the same as those of Seyfert nuclei. The fact that quasars were nuclei of galaxies in a luminous phase was demonstrated definitively only in the 1980s, twenty years later, when the pictures obtained with good receptors on large ground-based telescopes and on the Hubble telescope allowed us to distinguish the “host galaxy" surrounding the quasar.

Radio-galaxies were also soon considered as being related to quasars, owing to the large amount of energy released in the extended radio structure. Powerful radio galaxies are surrounded by two more or less symmetric radio “lobes" extended up to millions of light years on both sides of the galaxy, and the galaxy itself contains a compact radio source. A very thin elongated radio “jet" extending between the galaxy and the lobes is also observed, often only on one side of the galaxy (see Figure 1). After the development of Very Large Baseline Interferometry (VLBI) in the 1970s, the structure of the compact source was resolved, and for the first time in 1978 one got the proof that a tiny source with a dimension of one light year located *inside the galactic nucleus* was the origin of the jet and the radio lobes (and of all the energy stocked in them), as beautifully seen in the case of NGC 6251 (Figure 3). So radio galaxies, Seyfert nuclei, and quasars, appeared clearly linked with some kind of “activity" taking place inside the nucleus of a galaxy. A bunch of other types of objects were also considered as related to quasars. The reasons of this great diversity became clear only after the discovery of the “Unified Scheme" discussed below.

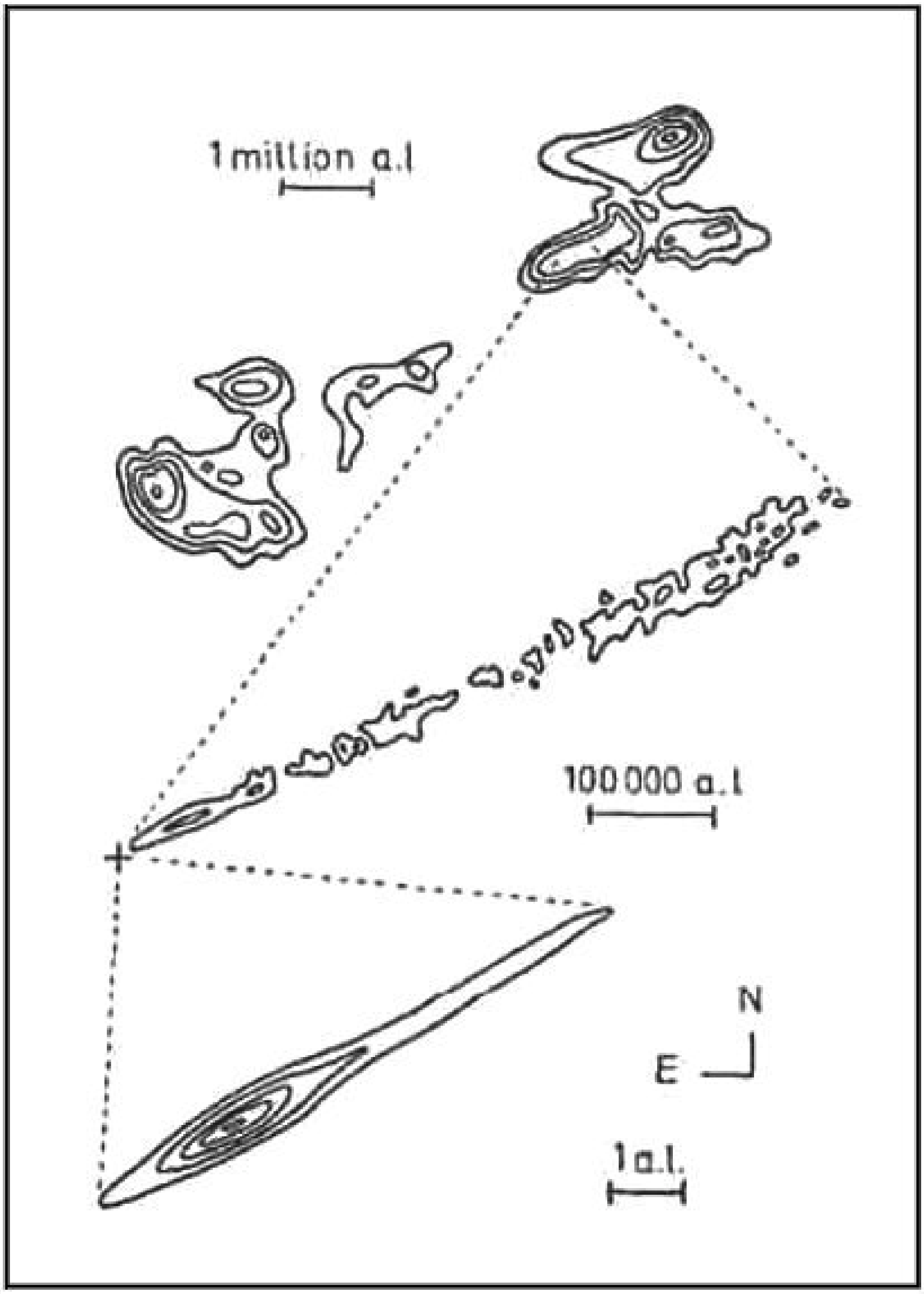

Figure 3. A radio map of the galaxy NGC 6251 at different scales, as it was published in 1978 by Readhead, Cohen and Blandford. It shows clearly that the large radio lobes are ejected by a tiny source at the position of the galactic nucleus. Courtesy Roger Blandford.

Until 1980 no consensus was reached on the origin of the enormous power of quasars associated with a very small dimension. Several models were proposed: front collisions of stars with a high velocity, explosions of supernovae in chains, “flares" at the galactic scale, etc. The most popular was the “supermassive star" energized by nuclear reactions or by pulsations leading to gravitational release. After the discovery of the first pulsars in 1968, “supermassive rotators" were also privileged, because massive stars are highly unstable and can be stabilized by rotation. All these models had theoretical problems and they did not agree with the observations when the properties of the electromagnetic spectrum were better known, so they had to be finally abandoned.

However, some people have guessed immediately the correct explanation. Already in 1964, two well known astrophysicists, the American Salpeter and the Russian Zel'dovich, suggested independently that a massive black hole was present in these objects, and Salpeter proposed that the matter and the angular momentum transport required for accretion onto the black hole was accomplished via a turbulent viscosity (this is exactly the presently accepted view). But astronomers at first did not take this idea seriously. Though black holes became rapidly quite popular among theoretical physicists, most astronomers considered them as an utopia, in no case associated with energy release in quasars. Lynden-Bell reiterated the proposition in 1970 at the Vatican Conference on "Nuclei of Galaxies', but the 25 famous astronomers attending the meeting did apparently not realize that this model could be the right one.

After the discovery of "stellar black holes" in binary systems, the idea that black holes could exist began to be accepted, all the more so that neutron stars - also strange bodies whose existence was predicted already in the 1930s - have been discovered as pulsars a few years before. Then Martin Rees produced in 1977 what he called "the flow chart" of a galactic nucleus: he showed that its fate is to lead inevitably through several different ways to the buildup of a "Super-Massive Black Hole", million to billion times more massive than a stellar black hole, in less than the lifetime of the galaxy itself. More and more people gave thus their adhesion to the model, since supermassive black holes were considered this time in a realistic astrophysical context.

Part of the difficulty with the acceptance of the accretion onto massive black holes as the source of activity came from the fact that the first discovered objects - radio-loud quasars - showed directly the effect of ejection from the nucleus, in the form of spectacular jets. This outflow, as well as the presence of relativistic particles emitting synchrotron radiation, seemed to imply some explosion mechanism. The solution to the puzzle came with time. First, Sandage found soon some "radio-quiet" quasars; they are actually ten times more numerous than radio-loud quasars. Then, in 1978, Greg Shields found the key argument: he showed that the optical and ultraviolet light of some quasars was better explained not by the synchrotron mechanism, but with another mechanism, this time directly related to the black hole: the radiation of an "accretion disk" driving the gas towards the black hole. One can consider that it was the death sentence to the other models, and the real beginning of the "accretion onto a supermassive black hole" paradigm for the central engine of all objects with active nuclei. We now know that active galaxies, when eating, spill out some fraction of the 'soup' but it is the 'eating' that keeps them alive.

Since the basic mechanism operating in quasars, radiogalaxies, Seyfert galaxies, and all other galaxies with nuclei showing non-stellar emission, is the same, we now frequently refer to all these objects as "Active Galactic Nuclei", or shortly AGN.

1.3. Accretion Onto Supermassive Black Holes: Why It Works So Well?

Like all massive objects, black holes attract surrounding material. Gas "falls" onto the black hole while emitting radiation, exactly like a shooting star which is heated and partly evaporated in the earth atmosphere. In the case of a black hole, the amount of radiated energy can be very large, up to 30% of the rest mass energy of the falling body, m_0c^2. This is possible because an infalling particle reaches a velocity close to the speed of light, thus gaining a very large kinetic energy at the expense of the potential (gravitational) energy. A significant fraction of this energy can be ultimately converted into heat and radiated away before the particle crosses the black hole horizon. The fraction of the rest mass converted into energy is thus much larger than the 0.7% obtained in stars energized by nuclear reactions. This is already a good reason to prefer accretion onto a black hole to any other process of energy production, because it minimizes the fuel rate, and thus the mass, of the "central engine".

The masses involved are nevertheless huge, as we can easily estimate. The black hole (or any other object) cannot be powered by accretion and radiate this energy away at an arbitrarily rate. If the emitted radiation is too high, the radiation pressure more than counter-balances the force of gravity and the surrounding material starts to be expelled. Thus, the luminosity of an object cannot rise above the value called the "Eddington luminosity" $L_{\rm Edd}$, equal to $1.5 10^{40} \frac{M\,({\rm BH})}{10^9\,{\rm M}_\odot}$ Watts, where ${\rm M}_\odot$ is the mass of the Sun. 10^{40} Watts is about the power of 3C 273 (if one takes into account the fraction of energy radiated in the non-visible range). Assuming that quasars are radiating close to their Eddington luminosity (it is actually the case) implies that the mass of the central object is about $10^9\,{\rm M}_\odot$.

Another circumstance pleads also strongly in favor of the black hole hypothesis: it minimizes the size of the engine, and the estimated sizes are consistent with observational constraints.

The theory of black holes is a major subject of theoretical studies, and we mention here only a few simple properties. Light or matter cannot escape from the black hole interior surrounded by a sphere where the escape velocity is equal to the light speed. This sphere is called the "horizon" of the black hole. For a non-rotating black hole, its radius is called the Schwarzschild radius, $R_{\rm Schw}$, and it is equal to $3\times10^{12} \frac{M\,({\rm BH})}{10^9\,{\rm M}_\odot}$ meters (note that the radius is proportional to the mass, so the bigger the mass, the less the *average* density). We have seen that the variation time scale of 3C273 is about a week, indicating a size of the emission region of 3×10^{14} m, i.e. about $100R_{\rm Schw}$ for a black hole of $10^9\,{\rm M}_\odot$. Such a size is comfortably larger than the black hole horizon, and actually quite consistent with more accurate theoretical considerations about the emission from accretion flow. At present the most tight constraints for the size of the optical emission of a quasar came from the gravitational lensing observed in the quasar Q2237+030 known also as the Einstein cross (2×10^{13} m).

The gas does not dash radially for the black hole, as its initial velocity is not necessarily (and even is never) directed exactly towards the center. It goes there by spiraling around the black hole, with the radial velocity frequently much smaller than the rotation velocity (the rotation velocity at the Schwarzschild radius is close to the light speed). In other words, the gas falls towards the black hole very slowly via an “accretion disk". A great challenge was to understand how this disk worked, and in particular how the gas was able to loose its angular momentum.

Thus at the beginning of the 1980s a theoretical framework was available to elaborate a detailed physical model for the central engine of quasars and AGN. Fortunately, space missions were beginning to provide abundant information on their emission properties in infrared, ultraviolet, X and gamma bands.

2. The Emission Properties of Radio-Quiet Quasars and AGN

In this section we concentrate on the description of the relatively bright AGN, with unobscured view towards the nucleus and without very strong radio emission. These objects give us the best possibility to observe the accretion pattern onto a central black hole. Good examples of such objects are radio-quiet quasars and some of the Seyfert galaxies.

2.1. The Broad Band Spectrum: The “Accretion Emission"

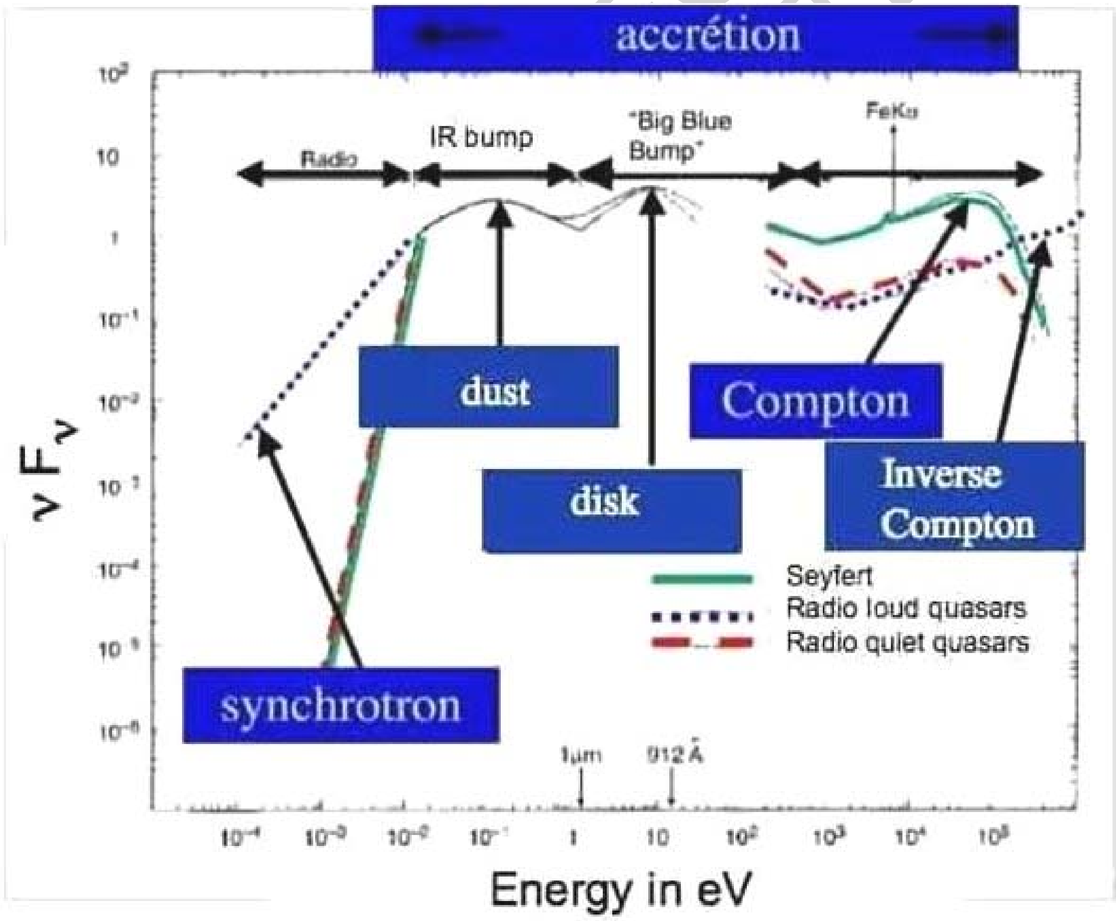

Figure 4. The typical Spectral Energy Distribution (SED) of quasars (radio-loud and radio-quiet) and radio-quiet active (Seyfert) galaxies, after Sanders et al. 1989. Seyfert and radio-quiet quasars have no radio and gamma-ray emission.

AGN are characterized by a “continuous" emission extending all over the electromagnetic spectrum, from the far infrared up to the hard X-ray range (Figure 4). Such broad-band data, as shown on the plot, were mostly collected with the use of satellites. Nevertheless, the spectral coverage is not complete since the extreme ultraviolet emission is obscured both by the Earth atmosphere and by the neutral hydrogen in our Galaxy. It introduces considerable uncertainty in the analysis of this emission. The spectrum can be actually divided into three components or “bumps". They are emitted by regions whose distance from the center increases with the wavelength, as it is assessed by their variability properties:

1. The infrared bump is constant in time scales of years and is thus probably emitted in a region larger than 10 lyrs (between 10^4 and $10^6 R_{\rm Schw}$).
2. The “Big Blue Bump" extends from the optical to the extreme ultraviolet, and even to soft X-rays. This component contains the dominant part of the total luminosity. It varies within time scales of days/years; it is produced by a region $\sim 10-100 R_{\rm Schw}$.
3. The X-ray bump varies within time scales of hours/days and is thus emitted by a small region, most probably close to the black hole ($\sim 10 R_{\rm Schw}$).

The presence of distinct spectral components indicates the presence of three separate physical components in the accretion flow.

The infrared bump is likely due to dust heated by the central ultraviolet and X-ray source, either in the outer regions of the accretion disk itself, or farther away in the “obscuring torus" accounting for the “Unified scheme" of AGN (cf. later).

The Big Blue Bump and the X-ray bump are most probably emitted by the inner regions of the accretion disk. Let us shortly describe how an accretion disk works. When the gas particles go closer to the black hole the rotation velocity increases; so the kinetic energy increases at the expense of the potential energy, because their sum (the total energy) must be preserved. The kinetic energy can then be converted into thermal energy and radiated away, allowing the gas to come even closer to the center. Performing such steps, the gas gives rise to the observed emission. Surprisingly, the simplest case for understanding is that of an inflow of material with high angular momentum. The gas particles then circulate around the black hole almost at circular orbits, only slowly drifting from one orbit to another. Since the total energy at circular orbit of radius R is equal to half of the potential energy ($-(1/2)G\,M/R$), the second half of the energy has to be radiated away. Crossing from one orbit of somewhat larger radius to another of somewhat smaller radius the particle has to radiate the difference between the total energies characteristic for these orbits, and this emission is radiated away from both sides of the narrow ring between the two orbits. The total emission from the ring is proportional to the number of particles passing from one orbit to another, i.e. the accretion rate, $\dot{M}$. Thus the total flux is a simple function of the disk radius, the black hole mass and the accretion rate, $F \propto GM\dot{M}/R^3$, independent of the details of the flow, including the viscosity mechanism. If the disk is optically thick and emits like a black body, so $F = \sigma T^4$, where σ is called the Stefan-Boltzmann constant, we even know the temperature distribution across the disk.

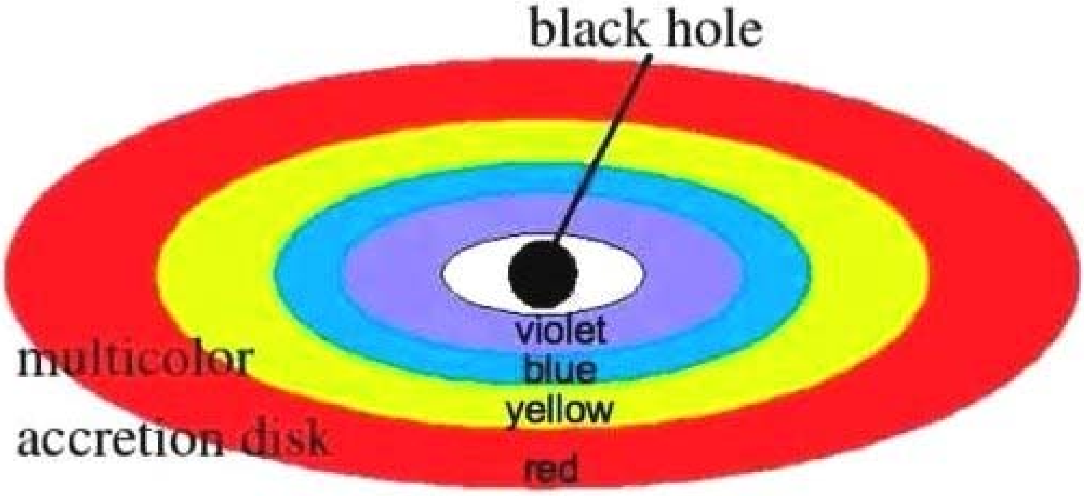

Figure 5. Schematic picture of the multicolor accretion disk around a black hole. The disk temperature is higher close to the black hole and lower at larger radii.

If different regions of the disk could be observed directly, the disk would appear like a multi-colored dish, whose color is red outwards and becomes progressively bluer, then violet and ultraviolet towards the interior (Figure 5). The optical emission corresponding to a temperature of about 10^4 K comes from $\sim 10^3 R_{\rm Schw}$ while extreme ultraviolet radiation corresponding to a temperature of a few 10^5 K is emitted typically at $\sim 10 R_{\rm Schw}$. Closer to the black hole, more complex formulae from general relativity must be used. The important effect is the existence of the innermost stable circular orbit (at $3R_{\rm Schw}$ for non-rotating black hole and closer in for a rotating one). The accretion disk ends there in a sense that the material from this orbit effortlessly plunges into the black hole as the gravity finally wins even over the angular momentum barrier. Unfortunately, the disk is much too small to be spatially resolved with the current instrumentation.

A difficulty is raised with this model by the observation of the “X-ray bump" extending up to hundreds of keV (see Figure 4). Hard X-ray emission is not predicted by the simple theory of accretion disks (contrary to X-ray stars which radiate in hard the X-ray range, because the masses of their black holes are about 10^{6-8} times smaller than those in active nuclei). The X-ray spectrum can be decomposed in several components: a hard power-law (i.e. the logarithm of the intensity is proportional to the logarithm of the frequency) with a turnover at a few tens keV, a soft X-ray excess, and a “reflection" component made of backscattered X-rays due to the irradiation of a surrounding “cold" medium, most probably the accretion disk itself (Figure 6).

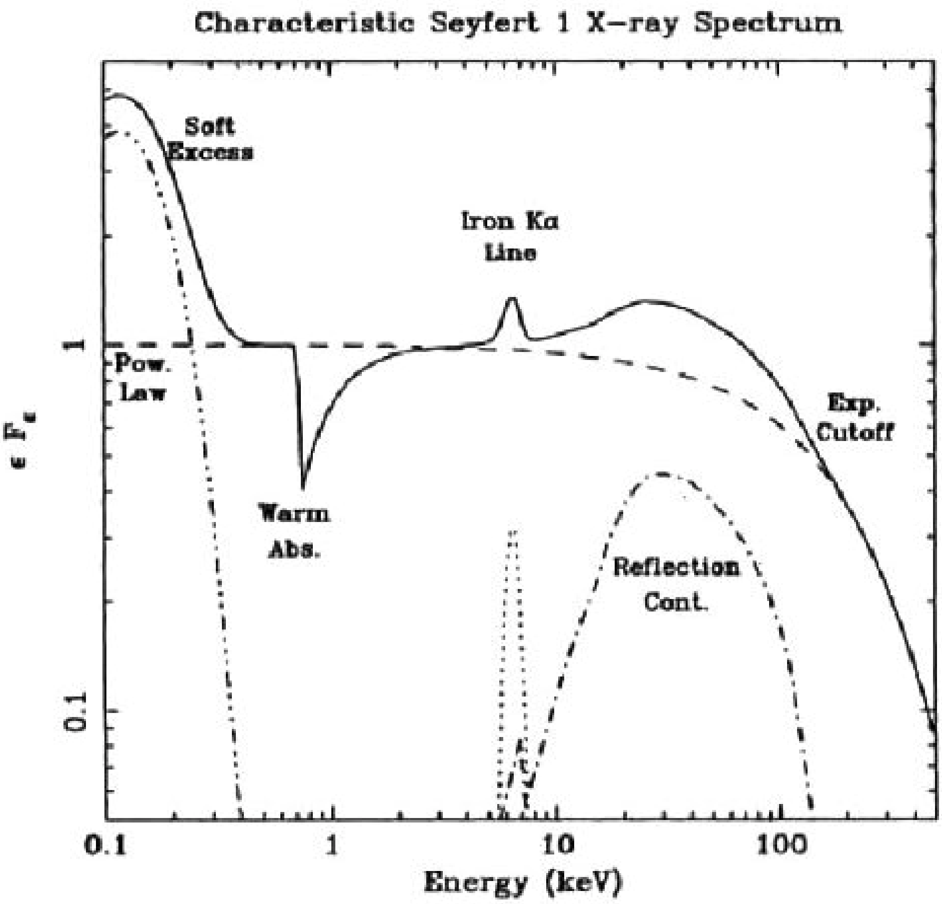

Figure 6. The different components of the X-ray spectrum. Source: A. Fabian, in Theory of Black Hole Accretion Disks, CUP 1998.

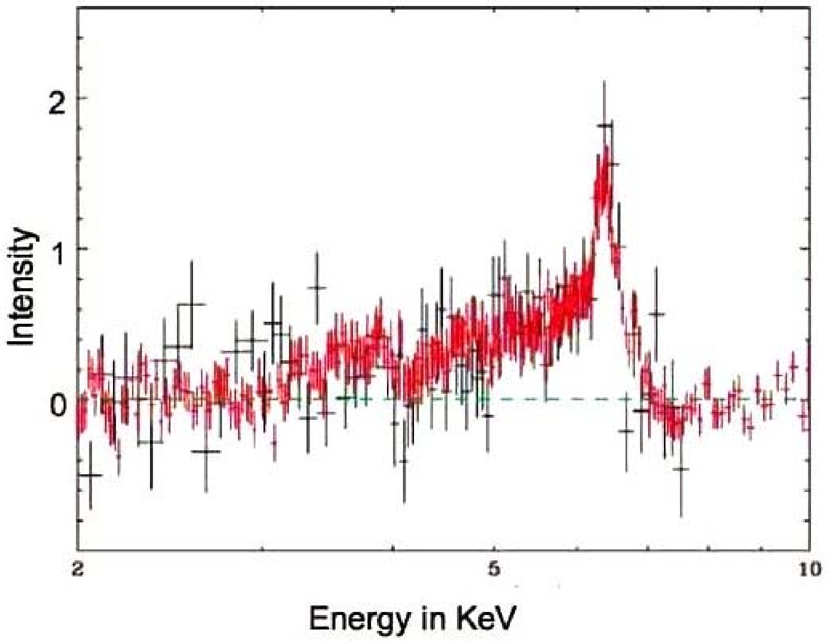

Figure7. Profile of the FeK line in MCG -6-30-15, observed by the X-ray missions Chandra and XMM-Newton, showing a very extended red wing. Source: A.J. Young 2005.

The presence of the reflection component is confirmed by the observation of an iron line at 6.4 keV, due to fluorescence (it is not seen in X-ray luminous objects, probably because iron is then too much ionized). This line displays often a peculiar profile with a broad red wing (Figure 7). Such a profile proves that the line photons have undergone a strong gravitational redshift, meaning that the line is formed sometimes at only one or two Schwarzschild radii from the black hole. The fact that the line is formed so close to the black hole is extremely important for testing the black hole rotation. If the black hole is not rotating, the gas should indeed plunge radially without radiating when it reaches $3R_{\mathrm{Schw}}$. But if on the contrary it is rapidly rotating (it is then called a Kerr black hole), the surrounding space itself is dragged into the rotation, and the gas can thus be spiraling and emitting down to $0.5R_{\mathrm{Schw}}$. So the extension of the red wing provides a diagnostic of the accretion flow in the strong gravity field of the black hole, and the issue is currently vigorously studied with new X-ray instruments.

In the most widely accepted model, the disk is thus made of two parts:

- The standard "cold" disk transporting the matter inward and radiating as the Big Blue Bump,
- A hot optically thin corona surrounding the inner regions of the disk emitting X-rays.

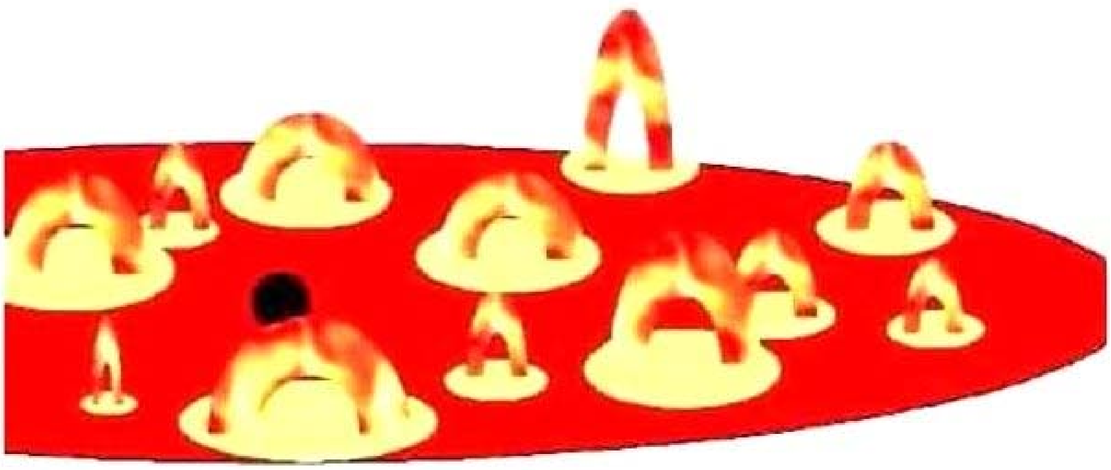

Figure 8. Schematic picture of the magnetic flares emerging from the accretion disks. The disk ultraviolet radiation is Comptonized by the hot flare plasma, and the energetic X-ray photons created in such way illuminate in turn the disk surface in the flare vicinity.

The corona is likely to be made of a few active regions similar to solar flares, sustained by magnetic loops anchored in the accretion disk (Figure 8). The X-ray emission of the plasma is caused by the Comptonization of the softer, less energetic optical/ultraviolet (e.g. disk) photons. A sketch of such scenario is shown in Figure 8 However, the exact geometry of the hot plasma is still under discussion, and the key question is whether the cold disk continues all the way down to the last circular orbit, or is actually disrupted at $10R_{\mathrm{Schw}}$ or more, and replaced by the optically thin hot flow. The shape of the iron line mentioned before in principle contains the answer to this question since the line forms only in the cold/disk part of the flow, but the interpretation of the observational data at present is not quite unique. What is more, the flow properties are likely to depend on the Eddington ratio, i.e. the ratio of the object luminosity to its Eddington luminosity. We will return to this issue in Section 3.5.

Until now, we have not mentioned the fate of stars orbiting in the vicinity of the black hole: like the gas, they are attracted by its enormous mass. When a star approaches very close to the black hole, it is disrupted by a huge tidal effect, because the gravitational potential is larger on the side of the star facing the black hole than on the other side. The denser the star, the closer it can approach the black hole without being disrupted: compact stars like white dwarfs, neutron stars or stellar black holes are always swallowed by a massive black hole without being broken. Moreover, if the radius of the black hole is large enough (remember that the radius is proportional to the mass) tidal effects do not occur before the stars have penetrated inside the horizon. As a consequence, all stars except supergiants are swallowed without being disrupted by a black hole more massive than $3\times10^8\,M_\odot$. If the black hole is less massive than $3\times10^8\,M_\odot$, "main sequence" stars like the sun are broken up and transformed into hot gas which is accreted via the disk after having radiated a fraction of its thermal energy, thus contributing to the luminosity. Such a phenomenon has probably been observed as it is the most likely explanation of a sudden temporary increase of the X-ray flux lasting for about a year, seen in several, generally non-active galaxies.

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Biographical Sketches

Suzy Collin was born in Paris, France, on September 10, 1938. She made academic studies in Paris University and got a master degree in physics in 1959. She spent a third cycle thesis in 1964 and a “state doctorat" in astrophysics in 1968.

In 1960, she became assistant professor at the Paris University. She taught physics and astronomy at all levels during 13 years, and worked in “Institut d’Astrophysique de Paris". In 1973 she got a full time research job in the “Centre de la Recherche Scientifique", where she became “Directeur de Recherches" in 1974. Since 2003, she is “emeritus researcher" at the Paris-Meudon Observatory. She was the supervisor of about 12 PhD theses.

In her thesis on Seyfert galaxies, she has predicted the variability of the broad lines and shown that the emission region is photo-ionized. Then she tackled different subjects, in particular on the heating of interstellar matter and on the chemical abundances in HII regions and in galaxies, but she worked essentially on the physics of Active Galactic Nuclei. She focused first on the problems of the Broad Emission Line spectrum, and since about 20 years, on the accretion disc structure and emission. She has published about 150 articles in scientific journals, and 50 in popular books or journals, as well as a popular book on quasars with Grazyna Stasinska (Editions du Rocher), several lecture notes, and she has presently a book in press on the history of quasars.

Dr. Collin is member of the International Astronomical Union, of the European Astronomical Society, of the French Physical Society, and of the French Astronomical Society, of which she was the president from 2000 to 2002.

Bożena Czerny was born in Kłodzko, Poland, in 1952. She was educated in Warsaw, she has got her PhD degree at the Copernicus Astronomical Center and she works at this institute till now, since 1996 as a professor. She published about 200 papers in scientific journals, most of them aimed at modeling accretion processes onto black holes, including Active Galactic Nuclei. She is a member of the International Astronomical Union, of The International Union of Pure and Applied Physics (secretary of the Commission 19 in years 2008-2010), and of the Polish Astronomical Society.