Introduction

In 1908, Edward Arthur Fath took an optical spectrum of a galaxy, NGC 1068, and found that the "spectrum is composite, showing both bright and absorption lines" (Fath 1909). In 1917, higher resolution spectra showed that these emission lines were similar to those observed in planetary nebulae (Slipher 1917). During the next decades, astronomers observed nuclear emission lines in several spiral nebula (see Fig 1.1). Thirty five years after Fath’s observations, Carl Keenan Seyfert realized that several of these galaxies formed a different group (Seyfert 1943). They had very broad emission lines (up to 8500 km s\(^{-1}\)) and the Hydrogen lines sometimes were broader than the other lines: the Seyfert galaxies. Although these discoveries still did not launch the study of active galaxies, astronomers were about to find that there was a whole hidden Universe waiting for them at long wavelengths.

In 1932, Karl Guthe Jansky, working for Bell Labs on transatlantic radio communications, discovered a "faint, steady hiss of unknown origin" (Jansky 1932). He found that this static was coming from our own galaxy and was stronger towards the constellation of Sagittarius, towards the center of the Milky Way. Radio astronomy was born.

Radio astronomy had a slow beginning, partly because of World War II, as most of the efforts in science and technology were put into military development. The good part is that once the war was over, some of these technologies were inherited by science\(^1\). The first discoveries were performed by engineers that (most of them) had turned into astronomers after World War II. New phenomena started to show up and, during the 1950s, it all finally started: pulsars, the cosmic microwave background, the 21 cm Hydrogen line and last but not least, quasars and active galactic nuclei, AGN.

It took some twenty to thirty years for astronomers to combine radio astronomy and active galaxies and realize what they had just discovered (even accidentally) but those

\(^1\)A curious anecdote: Some of the first radio telescopes in England and The Netherlands built right after the war used German-made radar dishes.
pioneers opened the doors for what has become one of the most fascinating and studied subjects in modern astronomy (see Shields 1999, for a review on history of AGN).

1.1 What are the AGN?

An active galactic nucleus is an object in the center of a galaxy whose spectrum cannot be explained just by starlight. The light emitted by the nucleus equals (Seyfert galaxy) or even exceeds (quasi stellar object, QSO) the total emission of the rest of the galaxy. This led to the idea that these QSOs were "stars with peculiar properties" (Matthews et al. 1961), as they looked like a star (they were point sources) but their spectra showed unusual properties for a star.

There are several types of AGN, classified according to their radio luminosity (radio loud or radio quiet) and spectral characteristics (Types 0, 1 or 2). The division in radio loud or radio quiet corresponds to objects bright or faint in radio compared to their own optical emission (Kellermann et al. 1989). Type 1 AGN are those with bright continuum and broad emission lines, Type 2 AGN have weak continuum and only narrow emission lines. The most active and variable AGN are sometimes classified as Type 0 but usually referred to by their names (BL Lacs, core dominated, etc, see Table 1.1).

Despite all these different types, there is light in the darkness. During the late 70s and 80s, astronomers realized that, in some cases, observations of AGN of a certain type resembled the properties of AGN of a different type. For instance, Antonucci & Miller (1985) found a hidden broad line region (BLR) in a Seyfert 2 galaxy; the polarised spectrum resembled that from a Seyfert 1. The absence of a BLR in Type 2 AGN could be explained if the central region of the AGN was "hidden" behind a screen (the torus) surrounding the nucleus. The properties of blazars (Type 0, radio loud AGN) could be easily explained if these AGN were Type 1 or Type 2 but observed along the radio axis. As the years passed, more types of AGN appeared to be related. In the early 90s, these unification models were so evolved that it seemed that there were only two really different classes of AGN, the radio loud and radio quiet, while the rest could be explained as being the same phenomenon, observed with different orientations.
1.1. What are the AGN?

Figure 1.2-. Artistic view of an AGN, from Urry & Padovani (1995). © PASP, reprinted with permission of the author.
<table>
<thead>
<tr>
<th></th>
<th>Type 2</th>
<th>Type 1</th>
<th>Type 0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radio quiet</td>
<td>LINER</td>
<td>Seyfert 2</td>
<td>Seyfert 1, Radio quiet quasars</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radio loud</td>
<td>NLRG FR I</td>
<td>NLRG FR II</td>
<td>BLRG, Lobe dominated quasars, Core dominated quasars</td>
</tr>
</tbody>
</table>

Table 1.1– Classification of AGN. This classification is orientative and objects show overlap. The line of sight decreases to the right of the table. Luminosity increases from top to bottom. Based on Urry & Padovani (1995) and Krolik (1999).

The Unification model is currently the most accepted model to explain the different AGN. It says that Type 0, 1 and 2 AGN, with the same radio loudness, might be the same phenomenon, but seen with different orientations (i.e. Barthel 1989; Antonucci 1993; Urry & Padovani 1995). Table 1.1 shows schematically how the type of AGN depends on the orientation towards the observer. Astronomers are also trying to understand what produces the difference between radio loud and radio quiet AGN and attempting to unify them according to their radio loudness. A very interesting model explains the difference in loudness with the spin of the central black hole, where fast spinning (Rees et al. 1982; Wilson & Colbert 1995; Meier 2002) central black holes would produce radio loud AGN while slow spinning central black holes would produce a radio quiet AGN. However, X-ray observations (Elvis et al. 2002) suggest that the majority of super-massive black holes rotate rapidly. Furthermore, the evolution of massive black holes in galactic nuclei is still not well understood and the difference between loud and quiet AGN is more complicated. Other phenomena must be taken into account, such as the size of the accretion disk, mass-to-energy conversion efficiency of the AGN, merging rates, size and angular momentum of the black hole (e.g. Peterson 1997; Véron-Cetty & Véron 2000; Yu & Tremaine 2002).

The physics are still not completely understood, but the current, most accepted model for the AGN consists of a super-massive black hole in the center, surrounded by a small (< 1pc) accretion disk, which is responsible for the huge amount of radiation we observe, (e.g., Rees 1984; Magorrian et al. 1998). The accretion disk widens in the outer regions, forming a torus (at 1 to a few tens of parsecs) that surrounds the whole AGN (see Figure 1.2). As the matter falls into the central hole, some of it will escape from the disk forming jets (which can extend for megaparsecs in the largest radio sources). The inner clouds (roughly the central 1 parsec) of the host galaxy form the broad line region (BLR) as the gas rotates faster closer to the black hole and the Doppler effect widens the emission lines of these clouds, and the outer clouds form the narrow line region (NLR), which can extend for a few kpc.

Although the basics of the model are probably correct, recent observations (e.g., Kondratko et al. 2005) suggest that some modifications must be made. The accretion mechanism could be more complicated than just a simple thin disk (e.g., Frank et al. 2002), the torus scenario is slowly being substituted by matter dragged by outflowing winds and creating the
obsuring region. This winds could also affect the emission mechanisms of the inner regions (e.g., Elvis 2000). The Unification model still has flaws beyond these corrections. While it explains most of the observed AGN, there are exceptions. Some of these exceptions can be explained as special cases where the source lacks a BLR, a special distribution of dust, etc. However, the Unification model does not consider factors that should be important in the life of AGN and their host galaxy, such as age, evolution and interaction with other objects.

1.2 Radio galaxies

Very simply put, a radio galaxy is a radio loud AGN where the optical nucleus is, at least, partially obscured. They are usually associated with elliptical galaxies and usually have radio jets that can extend for kiloparsecs or even megaparsecs. Their radio emission is thought to be mostly due to the synchrotron emission of relativistic electrons.

In 1974, Fanaroff and Riley classified morphologically the 3CR sources that were known to have two or more radio components (Fanaroff & Riley 1974). They measured the distance between the two brightest peaks and compared it with the total extent of the radio source. Those sources where the ratio was lower than 0.5 were classified as class I, those with ratio greater than 0.5 were classified as class II. Nowadays this classification is known as Fanaroff-Riley I and Fanaroff-Riley II, or shortly, FR I and FR II sources. FR II sources are also known as classical doubles.

Once a radio source is resolved, it can quickly be classified, in principle, as an FR I or FR II: FR I are usually weaker\(^2\) and show more distorted structures than the FR II. In FR I sources, the radio luminosity dims as we move away from the nucleus and most of them show two jets emerging from the core and ending in diffuse lobes or extended emission. We see the opposite effect in FR II, usually having a faint or undetected core, with jets or lobes that increase in luminosity with distance, and end in hot spots at the edges of the radio structure.

In the last 30 years, more differences have been found between FR I and FR II sources. Their radio and optical line emission luminosity show different correlations. There are also differences in the relation between line luminosity and optical magnitude of the galaxy (FR I show a correlation while the FR II do not). FR II are generally brighter than FR I for similar core and/or total radio powers (more details on these and other wavelength differences can be found in e.g. Baum et al. 1995, and references therein). The properties of the jets or how they are affected by the host galaxy must also be different (e.g., Bridle 1984; O’Dea 2002). At low redshift, FR II seem to be found in poorer clustering environments than FR I, while at higher redshift (\(z \sim 0.5\)), both classes are usually found in rich environments.

The literature contains many models and explanations trying to unify the Fanaroff-Riley sources, or explain the reason for their differences. I will just list a few here. In FR I galaxies the environments could be denser, slowing the jets to subsonic speeds while in FR II the

---

\(^2\)The limit is set by an absolute luminosity of \(P_{1.4\,\text{GHz}} \approx 10^{25}\, \text{W Hz}^{-1}\). Later, it was found that FR II are also brighter in optical wavelengths (e.g., Ledlow & Owen 1996) and infrared (Heckman et al. 1994).
surrounding media would not be dense enough to slow the jets down and they would manage to keep their supersonic velocities (detailed models on jets and FR sources can be found in e.g. Laing & Bridle 2004; Bicknell 1995). In this scenario, the supersonic jets of the FR II would end up hitting the external medium surrounding the source (e.g., De Young 1993; Peterson 1997). Also the fueling of the source and powering of the emission line gas seem to be different in FR I and FR II. FR I would be fueled slowly from the ISM and ICM, maybe through a cooling flow, while in FR II the accretion would occur rapidly. The emission lines of FR I would be powered by processes associated with the host galaxy (such as a cooling flow or photoionization by stars) and FR II would be powering their emission line gas with photons from the AGN (e.g., Baum et al. 1995; O’Dea 2002).

There are radio galaxies that do not fall exactly on the FR I or FR II class and other classifications can be found in the literature (e.g., Owen & Laing 1989; Gopal-Krishna & Wiita 2002). However, the Fanaroff-Riley classification is probably the most common. Another frequently used classification (that overlaps with the Fanaroff-Riley) is based on the spectral properties: if the spectrum shows broad emission lines we will have a Broad Line Radio Galaxy, if it only displays narrow lines we will have a Narrow Line Radio Galaxy. In the literature, they are usually referred by their acronyms NLRG and BLRG.

1.3 What are the GPS and CSS sources?

The Fanaroff-Riley classification is independent of size. If we classify radio galaxies according to their size, we will find that there is a sub-class of objects that have subgalactic scales, although the rest of their properties are basically the same of those of larger size radio galaxies. These small radio galaxies are the Gigahertz peaked-spectrum (GPS) and compact steep spectrum (CSS) sources.

GPS and CSS sources are types of radio loud AGN that constitute a significant fraction of the extragalactic radio sources (10% and 30%, respectively, in high frequency radio surveys). They are characterized by their convex (peaked) radio spectra, powerful emission ($P_{1.4\,\text{GHz}} \gtrsim 10^{28}$ W Hz$^{-1}$), low radio polarization and small size ($\lesssim 1$ kpc for GPS and from 1 to 20 kpc for the CSS sources). The GPS sources show their peak between 500 MHz and 10 GHz while the CSS have it at $\lesssim 500$ MHz, down to $\sim 30$ MHz, although these upper (10 GHz) and lower (30 MHz) limits are more due to observing and sample limitations than to physics or properties of the sources. The division between the two classes, GPS and CSS, is somewhat arbitrary and we can find different names or classifications depending on the morphologies or the authors, but basically they all comprehend the same objects: compact and medium symmetric objects (CSO and MSO), compact doubles or triples (i.e. Lister et al. 2003; Wilkinson et al. 1994; Conway et al. 1994; Phillips & Mutel 1981). For a review, see O’Dea (1998). I will adopt the GPS and CSS classification, as described, throughout the thesis.

There is still uncertainty about the relation between GPS/CSS sources and the larger radio galaxies, and how they relate with the other AGN. Several scenarios have been proposed, the most accepted of these is the young scenario, followed by the frustration scenario (e.g.,
1.3. What are the GPS and CSS sources?

Stanghellini et al. (2005). There are also other suggestions but these two seem to be the most accepted ones and, in the last years, the trends seem to favor the young scenario. I will discuss them separately below.

1.3.1 Recurrent or smothered sources

In this scenario, the nuclear activity stopped at some point and has recently started again forming a GPS or CSS source in the center (Baum et al. 1990; Stanghellini et al. 1990). This scenario is supported by the fact that $\sim 18\%$ of the GPS sources show large scale diffuse radio structure which could be the relic of the past nuclear activity (Stanghellini et al. 2005). Baum et al. (1990) also suggested the possibility that the expansion of the GPS sources being interrupted by a sudden increase in density in the central part of the source, instead of the nuclear activity being recurrent, what they call a smothered source. Many GPS sources also show complex VLBI morphologies (e.g., Stanghellini et al. 1997, 2001) which could support this model. However, there is much controversy surrounding the nature of some GPS sources with core-jet or complex morphologies: we could be observing large, beamed radio galaxies instead (see Section 1.6 for a detailed discussion).

1.3.2 Transient sources

In this scenario, GPS sources (CSO, e.g., Readhead et al. 1994, 1996a) are transient events ($\lesssim 10^4$ yr) in the life of the host. There are no strong arguments supporting or against this model.

1.3.3 Frustrated scenario

In this scenario, the GPS and CSS sources are old, evolved sources that have not been able to expand beyond the host galaxy (e.g., van Breugel et al. 1988; O’Dea et al. 1991; De Young 1993; Carvalho 1994, 1998). A very dense ISM could prevent the radio source expansion. Although the young scenario seems to be widely accepted, this old, frustrated version has not been completely ruled out yet.

1.3.4 Young scenario

In this scenario, the GPS sources would evolve into CSS sources in $\sim 10^6$ yr and then would evolve into FR I or FR II radio galaxies, once the jets break through the ISM surrounding the source and escape into the intergalactic medium. It was first suggested by Blake (1970) and has been developed along the years by different authors (i.e. Readhead & Hewish 1976; Phillips & Mutel 1982; Carvalho 1985; Hodges & Mutel 1987; Fanti et al. 1995; Readhead et al. 1996b; O’Dea & Baum 1997; Alexander 2000; Snellen & Schilizzi 2002).

The main arguments supporting this scenario are the similar properties and morphology of the sources, relation between the peak frequency and size, the absence of enough dense gas around the source to confine it (which is required by the other scenarios). The latest measurements of GPS expansion velocities (i.e. Polatidis & Conway 2003) are consistent with GPS sources being young ($\lesssim 10^3$ yr) and evolving into CSS, but they would need to slow down after the CSS phase to match the speeds measured in the larger radio galaxies.
The sources must undergo other changes in their evolution, as some of their properties (expansion velocities, luminosity or size distributions) do not match those observed in larger radio galaxies. The simplest explanation is that the interaction with the host is responsible for making these changes. However, this explanation has yet to be confirmed, and there is no definitive evidence of the link between GPS/CSS sources and large radio galaxies, as the studies are based on the similarity of properties and extrapolation of the relation between GPS and CSS.

1.4 Current model of the GPS and CSS sources

Although there are still uncertainties, many GPS and CSS sources are likely to be young radio galaxies expanding through the host, to become FR sources (e.g., de Vries 1999; Snellen et al. 2003b; Polatidis & Conway 2003). However, there is not a solid model that describes how this expansion takes place.

Quite a few models are still qualitative, but there have been different attempts to make an analytic model. Most of these have been developed based on self-similar expansion of the radio source. They are mainly variations on the Begelman (1996) model, including free-free absorption or synchrotron self-absorption and varying the jet or host physical parameters as new observations were obtained.

The main criticism is that the self-similarity is usually introduced empirically to explain the observations but with no solid physical argument to support self-similarity. It seems a little ad hoc to force a jet to cross a galaxy and maintain geometric relationships. Furthermore, it is not clear if other effects other than self-similarity could reproduce the observations and some models developed in the last years (e.g., Carvalho & O’Dea 2003; Tinti & De Zotti 2005) seem to match the data better without including self-similar growth.

Almost until middle of the 90s, astronomers did not realize that GPS and CSS could form a class of radio sources by themselves. It is not yet clear, especially for GPS, that all sources classified as GPS and CSS really fall in this group. This has created a difficult to avoid inertia, that we are only now being able to abandon. If we don’t know what is really a GPS/CSS source, we cannot plan systematic surveys to observe these sources, or certain properties, and test our models. Now that we are slowly starting to understand them, this is changing; but almost until mid 90s, all GPS/CSS samples were selected from surveys targeting general radio sources (3CR for example). These surveys had selection criteria that not necessarily would apply to GPS and CSS. For example, the steepness of the spectra and position of the peak would make a certain type of GPS/CSS not fall into the selection criteria of some surveys. Then, we could only test our models on certain GPS/CSS without knowing if they were representative of the whole GPS/CSS population or if the selection criteria had cut out a certain type that would not fit our model and could be more representative of the GPS/CSS population. Most of the uncertainties in the nature of GPS/CSS still come from not knowing what we are missing in our samples or if everything that looks as GPS or CSS really fits the definition. Chapters 2 and 3 of this thesis re-classify some of these objects.
Taking all of the above into account, the most accepted models of GPS and CSS sources agree that the peak in the radio spectra is due to synchrotron self-absorption and that the radio source strongly interacts with the host while it expands. GPS sources seem to increase in radio luminosity as they cross the core of the host. Once they leave the core (their size makes them now CSS) the radio source starts dimming as it grows (and the density of the host decreases). This scenario, although still with some problems, could unify GPS, CSS and FR galaxies. A good model unifying GPS/CSS galaxies and quasars or the different distributions with redshift is still needed.

1.5 The spectral shape. Synchrotron self-absorption

The spectral shape of GPS and CSS sources is thought to be due to synchrotron emission and self-absorption (Figure 1.3, Snellen et al. 2000). Where the source is optically thin, the spectrum is produced by normal synchrotron emission and follows a power law (e.g., Kellermann 1964; Ginzburg & Syrovatskii 1965):

\[ F_{\nu} \sim \nu^{\alpha} \]

where \( \alpha \) is called spectral index and lies between \(-1.7\) and \(-0.5\) for the optically thin region of most extragalactic radio sources, depending on source morphology and observing frequency.

The cloud where the synchrotron emission is produced may reabsorb the lower frequencies of its own emission (e.g., Ginzburg & Syrovatskii 1969). This phenomenon is called synchrotron self-absorption and produces a spectrum of the form:

\[ F_{\nu} \sim \nu^{5/2} \]

This produces a spectrum with the shape shown if Figure 1.3. The frequency corresponding to the maximum flux emission, the turnover frequency, \( \nu_m \), is given by:

\[ \nu_m \sim B^{1/5} S_m^{2/5} \theta^{-4/5} \]  \hspace{1cm} (1.1)

where \( B \) is the magnetic field, \( S_m \) is the flux density at the peak and \( \theta \) is the angular size of the source (e.g., Pacholczyk 1970). The position of the turnover frequency carries information on the source size (which has the largest contribution) and physical properties, so studying the turnover frequency of a source will yield information on its properties:

- **Redshift.** It has been found that GPS sources happen preferentially at higher redshifts (e.g., O’Dea et al. 1990; de Vries et al. 1997a) so we would expect them to be more compact, as the turnover frequency is proportional to \( \theta^{-4/5} \), and it would imply denser environments at high redshifts. However, this result might be due to detection limits, as for the steep spectrum sources, the redshift could move the spectra far enough so the flux density of the source at our observed frequencies is below the detection limits.

- **Linear size.** Fanti et al. (1990) found an anti-correlation between the linear size and turnover frequency of CSS sources. O’Dea & Baum (1997) studied the relation
between linear size of the source and intrinsic turnover frequency, but now combin-
ing both GPS and CSS sources in the sample. They found that the anti-correlation also occurred for the combined sample, suggesting similar properties for GPS and CSS sources (although nothing directly implies that the sources evolve following this cor-
relation), and that this correlation was the same also for quasars and radio galaxies:

\[ \nu_m \propto (\text{Linear Size})^{-0.65} \]

The spectral shape observed in GPS and CSS sources can also be reproduced by free-
free absorption processes (e.g. Tingay et al. 1997; Bicknell et al. 1997) but to reproduce the observations, another factor must be invoked (i.e. an absorption screen). Although there are still authors supporting the free-free absorption as the process causing the spectrum shape, the main stream seems to favor the synchrotron self-absorption (e.g., Snellen et al. 2003b), as it is a much simpler argument and can reproduce the observations without including other factors in the source. However, free-free absorption cannot completely be ruled out nor can a combination of both processes.

## 1.6 GPS quasars

There is substantial controversy surrounding GPS quasars (e.g., Snellen 1997). According to the unification model, they should be the same type of object as the GPS galaxies with different orientation. However, observations seem to disagree:
GPS quasars are clearly more abundant than galaxies (e.g., Dallacasa et al. 2000) and are found at all redshifts (peaking at $z \sim 2 - 3$) while GPS galaxies appear only below $z \sim 1$ (O’Dea et al. 1991). This difference in redshift is likely to be genuine and not due to selection or similar effects (Snellen et al. 1999).

GPS quasars show higher values of intrinsic and observed turnover frequencies than GPS galaxies suggesting that GPS quasars may be more compact than the GPS galaxies (e.g., Stanghellini et al. 1998).

Observations suggest that the spectra of GPS quasars originate in compact regions, close to the nucleus while in galaxies it seems to come from hot spots with large range of sizes (e.g., Stanghellini 2003).

These differences have led to the hypothesis that GPS quasars could be a different type of object, not related to CSS sources or GPS galaxies or the models discussed in Sections 1.3 and 1.4 (Stanghellini et al. 2005).

What then are the GPS quasars? It has been widely accepted that CSS and GPS sources are not affected by Doppler boosting\(^3\). Most of the CSS sources have lobes of similar intensities and their jet velocities are not relativistic. This is also true for GPS galaxies. However, GPS quasars may be affected by beaming (de Vries et al. 1997a; Stanghellini et al. 1998). This beaming can make a flat-spectrum quasar look like a GPS quasar and vice-versa.

If a flat-spectrum quasar has its jets close to the line of sight, Doppler boosting can be important enough to change its spectrum (e.g., Lister 2003; Melrose 1996), as Doppler boosting would move the individual spectra of each component (equation 1.1). At some stage, variation in the intensity of components of the jet (a perturbation or shock wave moving along the jet, a single homogeneous component dominating the radio spectrum) can modify the spectra of the components in such a way that the total composite spectrum of the quasar will look like a real GPS spectrum. It is possible that most (if not all) observed GPS quasars could be large quasars with apparent GPS source spectra (Snellen 2004, private communication, see also e.g., Snellen et al. 1999).

So far, all the GPS samples may be contaminated by these non-GPS quasars. However there are ways of unveiling them. The conditions for a flat-spectrum quasar to create a GPS looking spectrum are rather random and temporal. Then, we expect to observe variability, which would not be present in a GPS source. The closer we are to the jet line, the faster the variations in the jet propagate, so we should be able to observe variations in the quasar radio spectra in (astronomically) short periods of time. Some work has already been done in this line finding that, in fact, sources that some years ago looked as GPS quasars, now show a completely different, non-GPS, radio spectrum (e.g., Tinti et al. 2005, and Chapter 3 of this thesis).

Some GPS and CSS quasars with core-jet or complex morphologies could be large sources observed along the radio axis. The high redshift of the GPS quasars could make extended radio emission to fall under the detection limits (Stanghellini 2003). High resolution,
Figure 1.4-. Snellen et al. (1998b) model and representation of how Doppler boosting can change the spectrum of a source. The length of the arrows is proportional to the speed of the component. Doppler boosting is not important in galaxies but it can completely change the spectrum and appearance of a source when observed along the jet axis. Reprinted with permission of the author.
deep VLBI imaging of these sources should also help decontaminating the samples.

It is worth noting that the opposite effect can also be present. A GPS source could look like a flat-spectrum quasar. Snellen et al. (1998b) have proposed a model where the jets decelerate as they expand. In this model the inner components of the jet propagate faster than the outer ones and are, therefore, more affected by Doppler boosting. The Doppler boosting effect is mainly noticed along the line of propagation, and decreases with viewing angle. So, combining both effects, a galaxy with a GPS spectrum can look like a flat-spectrum quasar (probably core-jet) when observed along the jet line (see Figure 1.4). A direct consequence is that we may (and most likely do) have GPS quasars hiding in flat-spectrum quasar samples.

1.7 Thesis project

By the beginning of this thesis, GPS and CSS sources stood as different classes of objects by themselves, and a lot of research had just been carried out. However, there were still questions to be answered. In my opinion, the two main questions concerning GPS and CSS sources were:

1) Where do they stand in relation with the other radio sources and AGN?

2) How do GPS/CSS interrelate with their host?

Both questions had been around for some time, however, the first one was sooner to be answered. There were two important workshops held on 1999 (Life cycles of radio galaxies\textsuperscript{4}) and 2002 (The Third Workshop on CSS and GPS radio sources\textsuperscript{5}). In the first one, participants showed growing evidence supporting the young scenario. By the end of the 2002 workshop, most participants were convinced that GPS and CSS sources are (or seem to be) young.

Research had been carried out focusing on the interrelation between the radio source and the host. However it was a by far less active field. The main developments on this subject were done on alignment effect of the radio source and the line emission gas. This thesis takes it from there and advances in our understanding of the interrelation between the radio source and the host and how it is affecting both.

Other issues addressed in the thesis:

3) Mapping of compact radio sources.

4) Enlargement and improvement of GPS and CSS samples.

5) Properties of the gas and stellar population of the host.

6) Ionization mechanisms of the gas in the host.

7) Gas content and distribution in the host.

8) First near-UV study of GPS and CSS sources.

9) AGN–starburst connection.

1.8 Thesis outline

Chapter 2 presents radio maps of compact sources in the Southern hemisphere. The data are being compared with other measurements to classify and look for unidentified GPS and CSS sources in the sample. Number statistics of GPS and CSS quasars and galaxies are presented and compared with the Northern hemisphere.

Chapter 3 presents optical observations of hosts of candidate GPS radio sources. Identification and spectroscopy of the hosts are carried out, aiming to complete the GPS identification and redshift entries of the O’Dea et al. (1991) GPS master list. New identifications, magnitudes, redshifts and emission line gas properties are reported. Models of stellar populations are compared with the observations. Literature data are collected to study previous GPS identifications.

Chapter 4 presents Hubble Space Telescope long slit spectroscopy of CSS sources, studying the ionization mechanisms of the emission line gas, as well as its properties. All sources show a combination of photoionization and –fast– shock ionization. The expansion of the radio source is clearly affecting the optical emission properties of the host.

Chapters 5 and 6 present high resolution radio imaging and spectroscopy of two CSS sources and a GPS source, and study the contents, distribution and properties of cold gas in the host, revealing that it seems to be associated with the emission line gas and presenting a completely new interpretation of an old known GPS source.

Chapter 7 presents the first study of the near-UV emission in hosts of GPS and CSS sources. Alignment between the radio source and UV emission of the host is found, as well as small UV emitting regions, consistent with recent star formation. A comparative study with large radio sources is presented. The connection between bursts of star formation and the presence of a powerful radio source is explored.

Chapter 8 summarizes the main results of this thesis and discusses its implications. It also describes the work carried out by other groups concerning GPS and CSS sources and attempts to make a coherent picture. The last section of the chapter suggests possible lines of future research.