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MODELS OF EMISSION LINE PROFILES AND SPECTRAL ENERGY DISTRIBUTIONS TO CHARACTERIZE THE MULTIPLE FREQUENCY PROPERTIES OF AGNs

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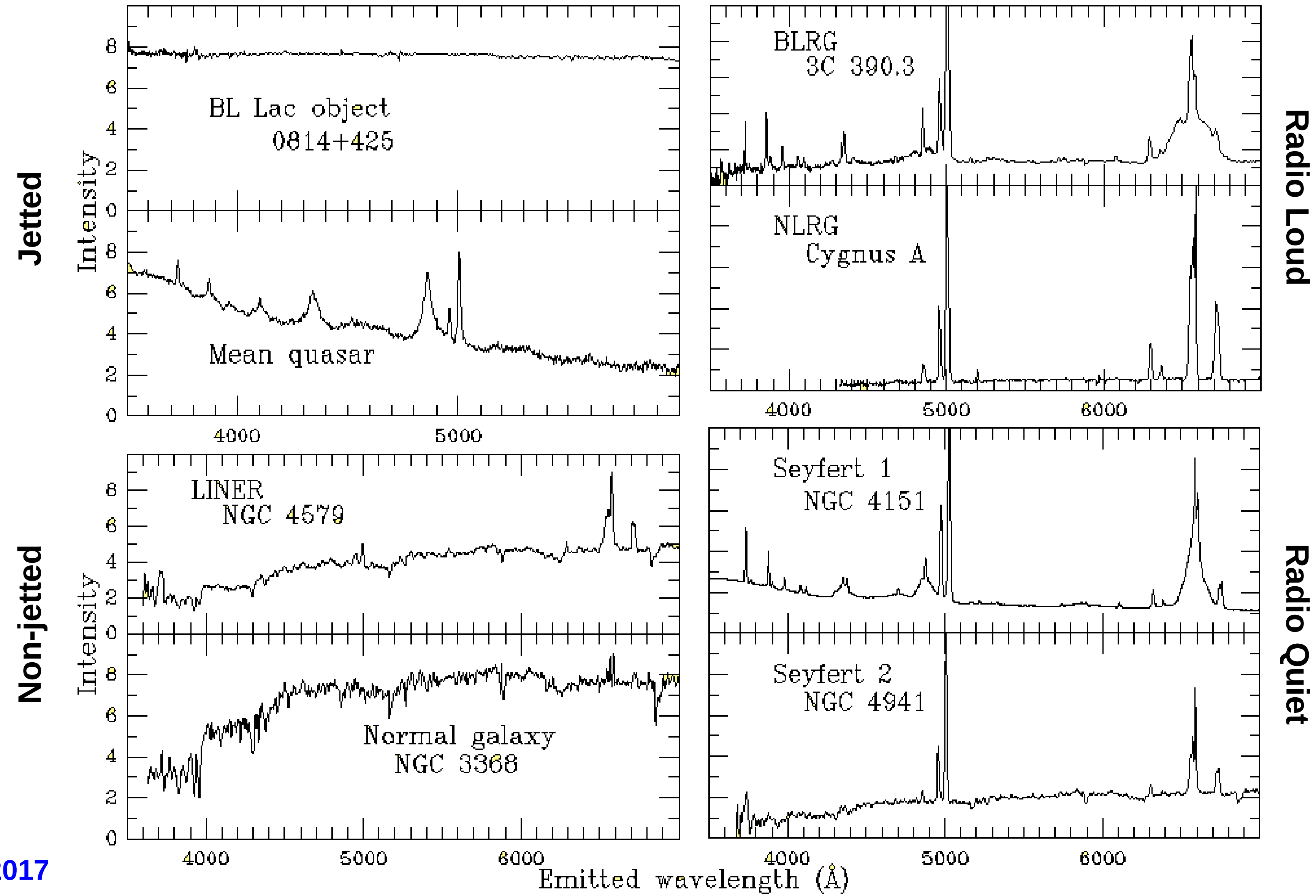
How to classify sources in catalogues

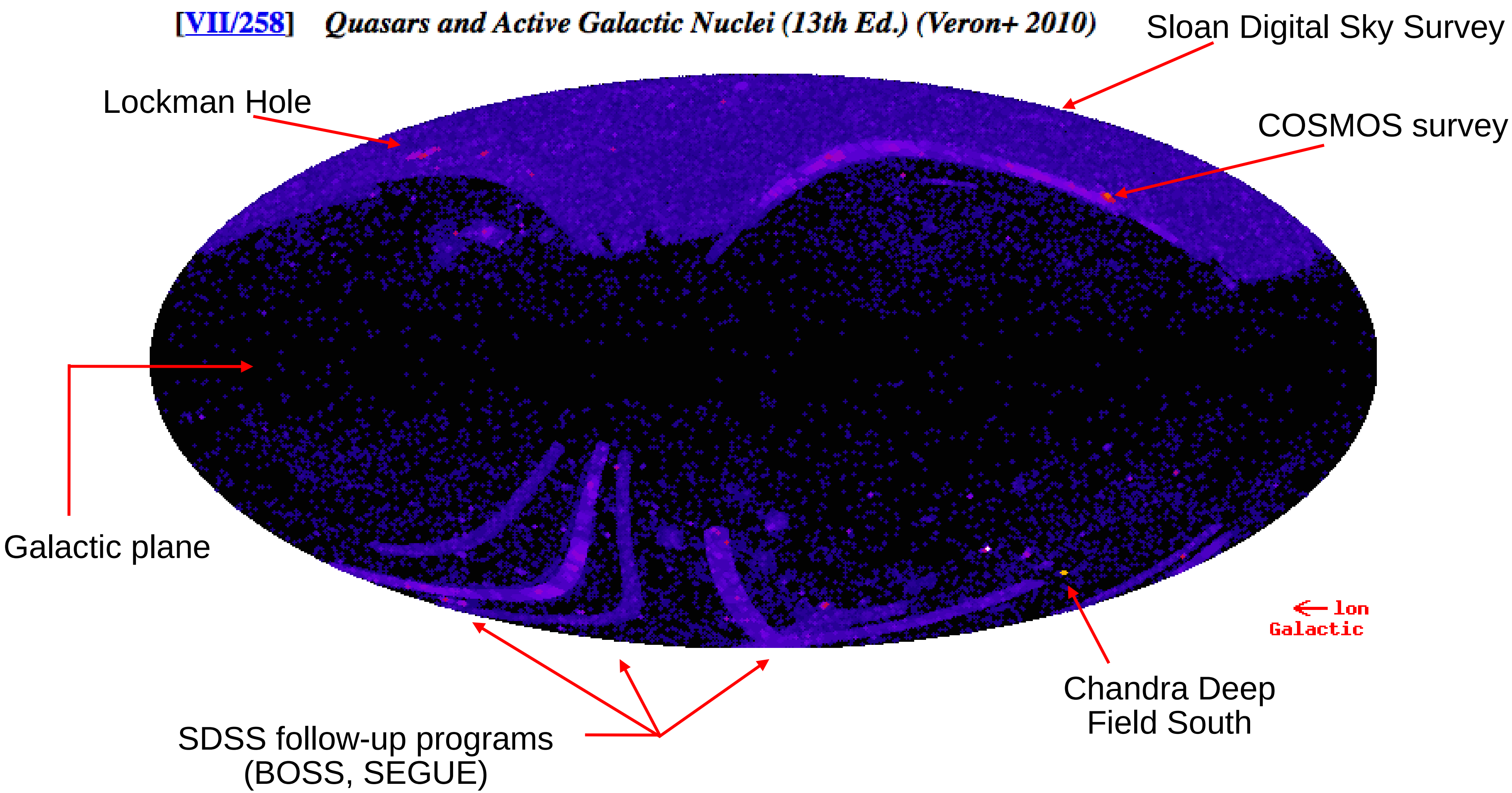
Classification is strictly connected with **phenomenological understanding**.

Proper distinction of classes and statistical properties of populations are key ingredients to investigate the nature of AGNs, their evolution, and their role in the process of galaxy formation.



The Universe of Active Galactic Nuclei

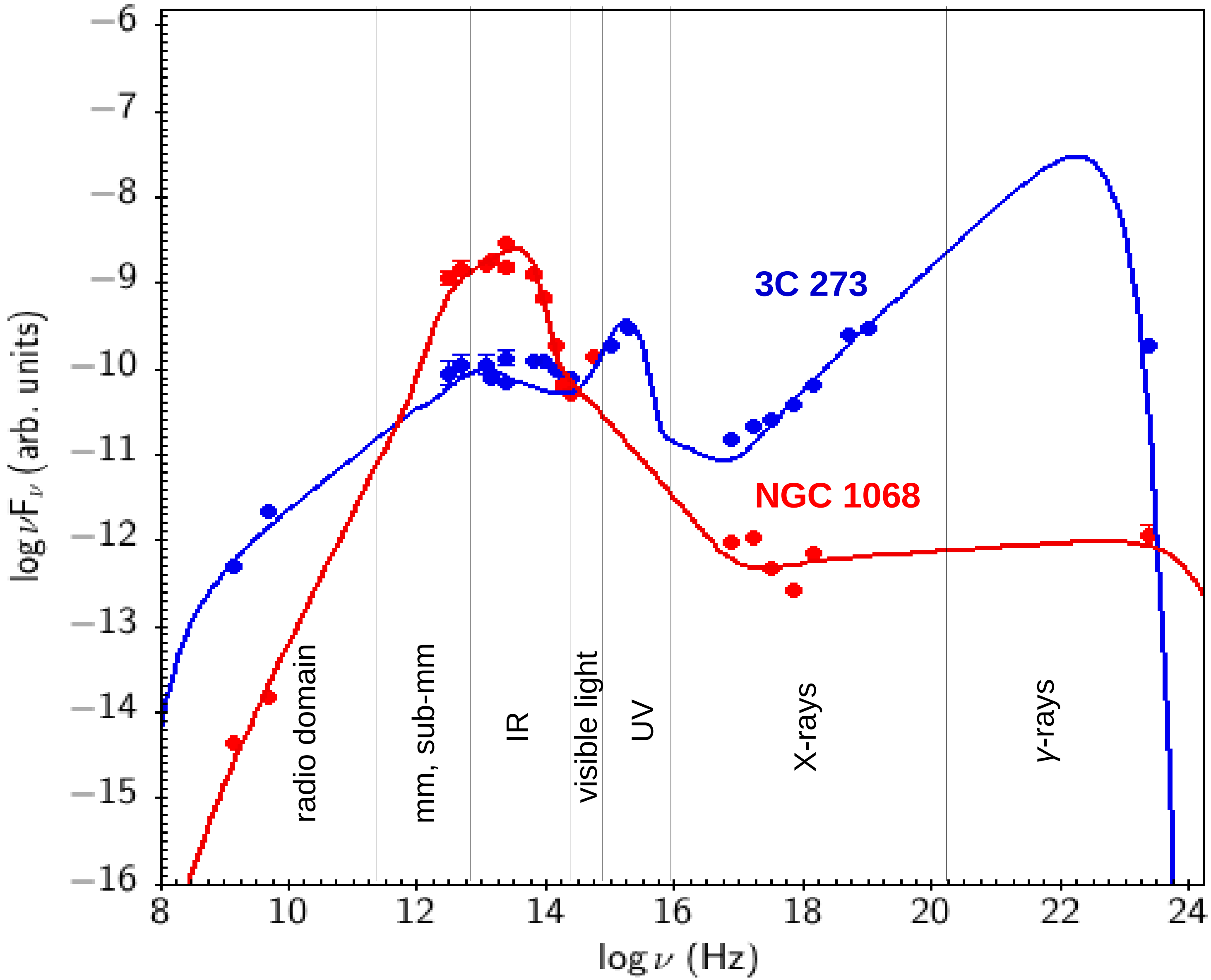
- Recent estimates: 168940 objects catalogued in the sky (Veron-Cetty & Veron, 2010)
- Distributed from the local Universe (z = 0.002) up to the farthest sources (z > 7)
- Classification, in many cases, is still an open problem



Possibly, millions **detected**, yet not **identified**!!!

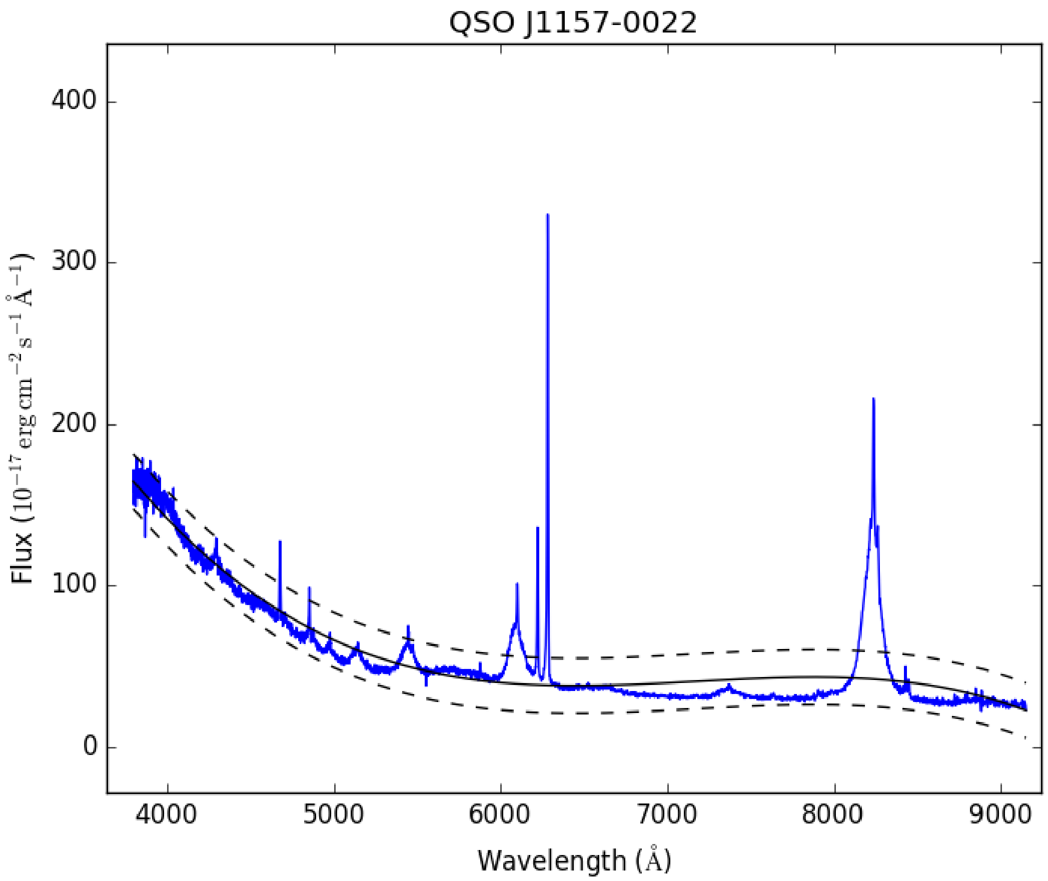
Multiple frequency properties

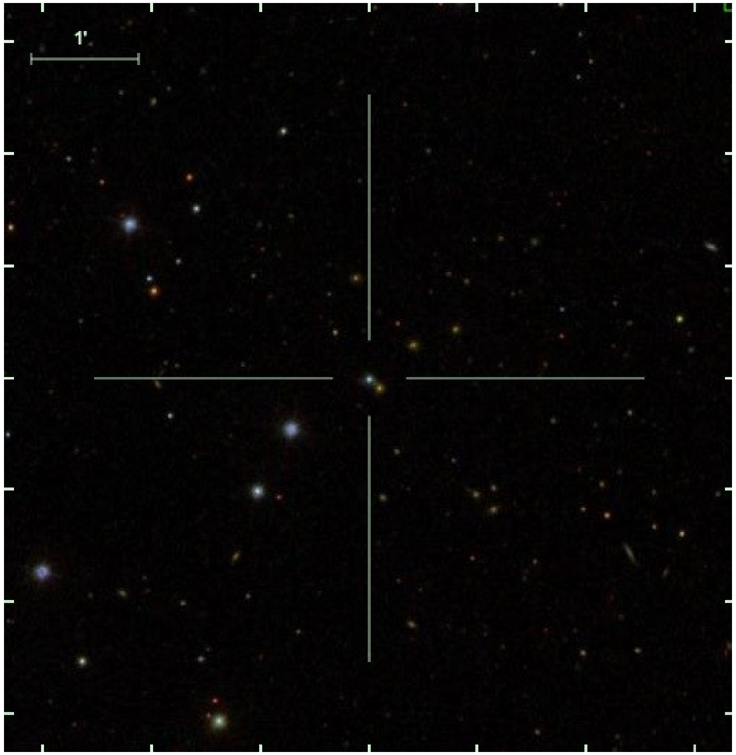
Together with characteristic optical spectra, AGNs are sources of electromagnetic radiation spanning over **10 orders of magnitude in frequency**. The overall appearance is consistent with an increasing amount of obscuration, moving from broad lined type 1 objects to narrow line emitting type 2 sources. Searching for AGN through their **extended emission frequency range** is an attractive opportunity.



Machine driven spectral classification

Many catalogues have been connected with large spectroscopic survey programs, creating databases that store millions of entries. **Manual inspection of all the data is not possible**. Automated procedures to classify observations according to a well defined set of parameters were consequently developed.

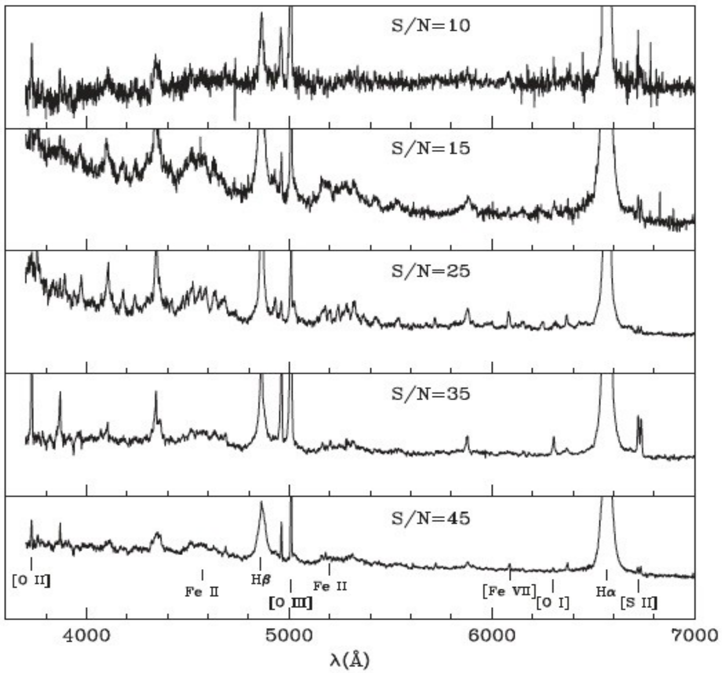


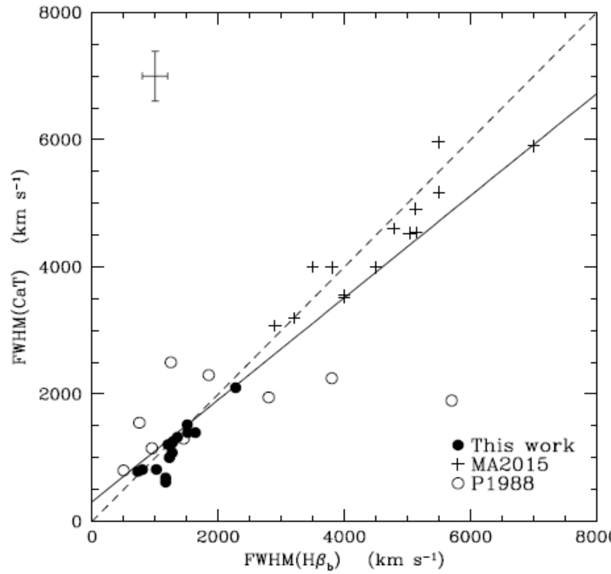


Based on a definition of **spectral continuum**, possibly weighted by proper data **quality flags**, machine driven databases are able to recognize and to classify **emission and absorption features** in spectra. The **Sloan Digital Sky Survey**, in the northern hemisphere, and the **6dF Galaxy Redshift Survey**, in the south, use these procedures for tasks like redshift measurement.

High level data products from surveys

SDSS offers access to **high level data products**: photometric measurements of point-like and extended sources (modelled with various profiles), extinction corrections, line identification, flux and profile measurements. The combination of selection criteria working on these parameters can reliably extract **statistically homogeneous samples** of targets from the database.





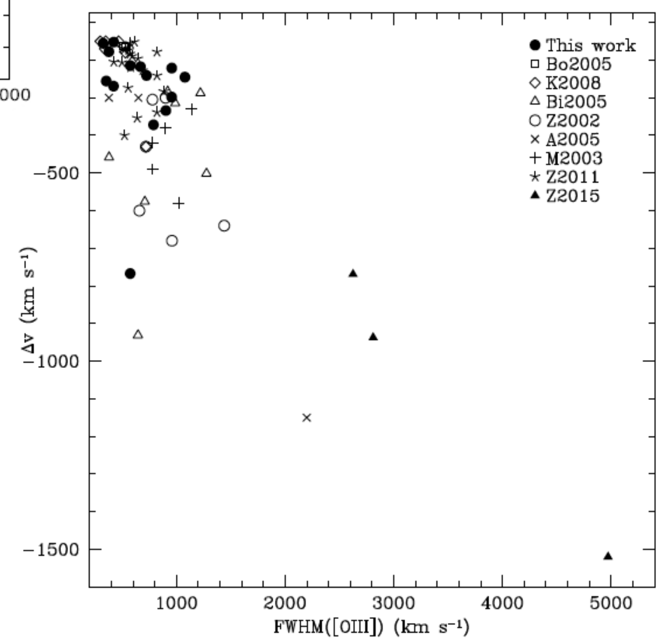
NLS1 galaxies in SDSS DR7:

2372 emission line spectra

(s/n$_{\lambda 6300}$ > 3, 0.028 < z < 0.345)

360 candidate NLS1

296 confirmed

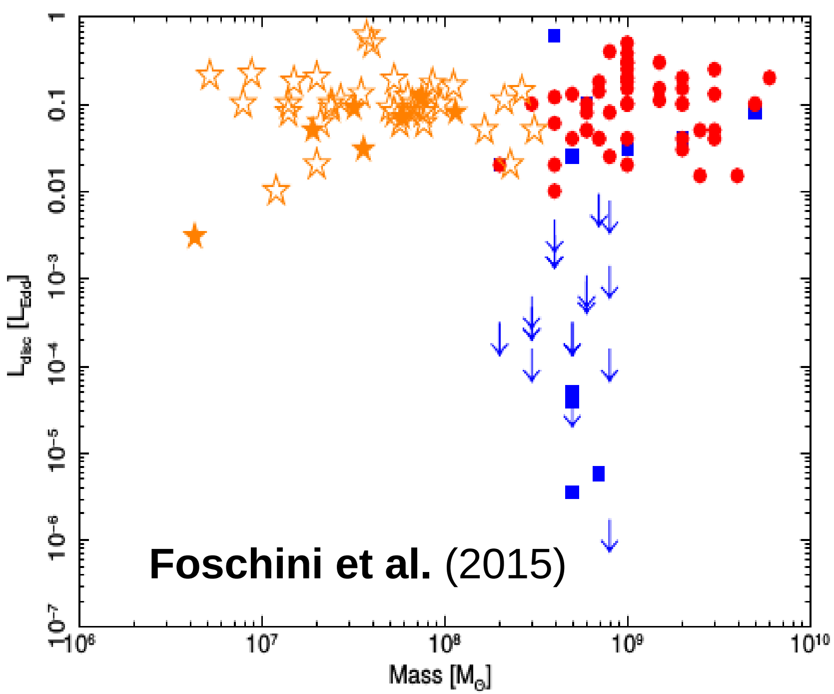


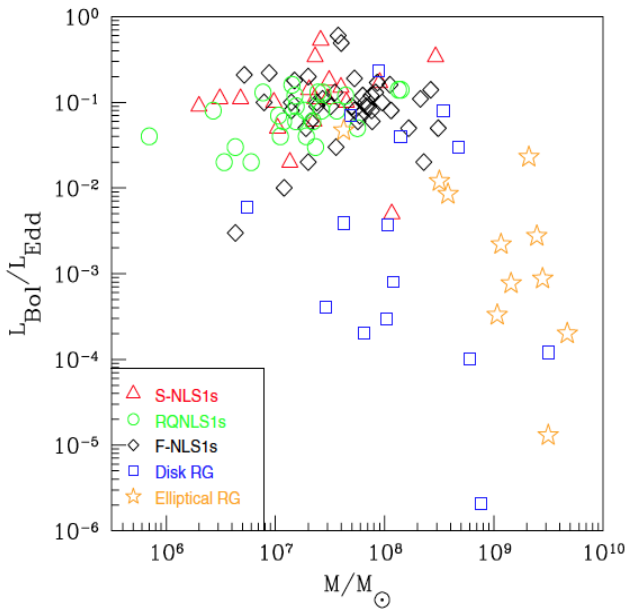
- Fe II & Ca II coming from the same part of the BLR
- Ca II triplet emission consistent with collisional excitation of Fe II
- broad lines with Lorentzian profiles (turbulent contribution to profile)
- turbulent NLR gas associated with fast out-flowing motions
- apparently continuous sequence towards broad lined AGNs

Cracco et al. (2016, MNRAS, 462, 1256-1280)

High level data products from surveys

It is possible to combine detailed spectroscopic information with multiple frequency observations, especially in presence of all-sky monitoring programs. Such possibility exists, particularly in the **radio** and in the **high energy** domain. The combination of these observations leads to perform statistical studies on specific source classes that are particularly well suited for the case of AGNs.





7% of NLS1 are radio-loud

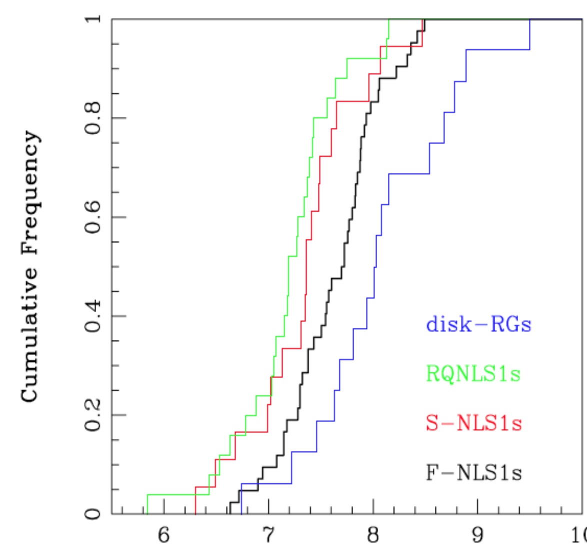
(Komossa et al. 2006)

Some detected in γ-rays

(Abdo et al. 2009)

To date **10 γ-NLS1** firmly

known

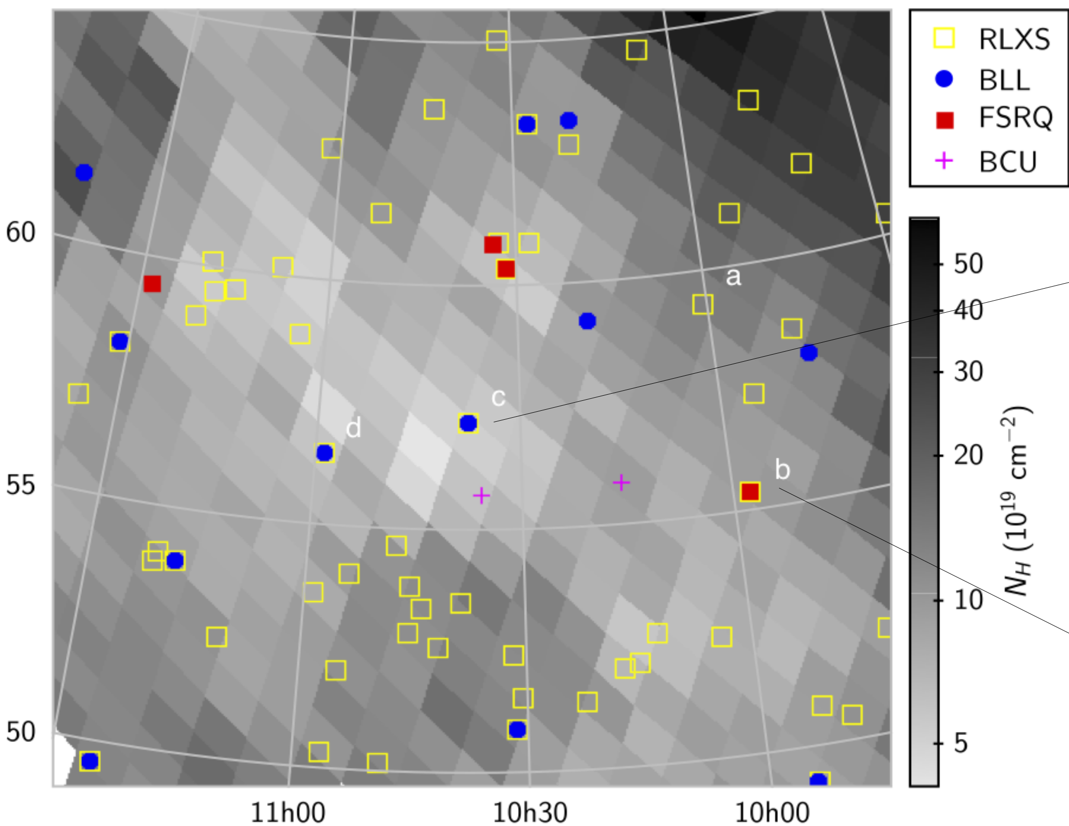


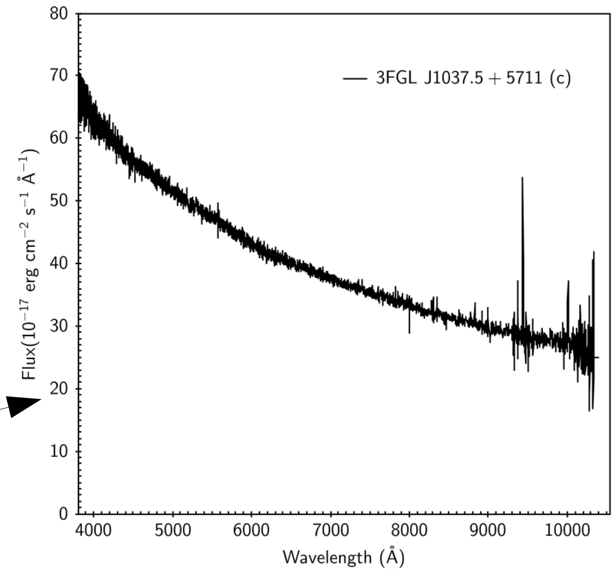
- NLS1 galaxies have low mass black holes accreting at high rates
- Flat spectrum radio loud sources represent the beamed population
- Steep spectrum radio loud and disk radio galaxies are good parent candidates
- Radio quiet NLS1 appear to follow a different evolutionary track
- NLS1s represent a crucial family to understand the evolution of AGNs

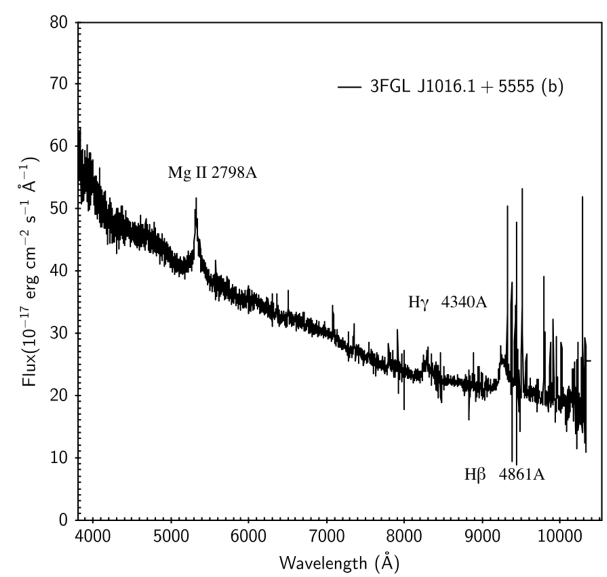
Berton et al. (2015, A&A, 578, A28)

Identification of *γ*-ray sources (100MeV – 300 GeV)

In the assumption that *γ*-ray emission from extragalactic sources is powered by **Inverse Compton** scattering on ultra-relativistic particles, the source is associated by looking at the corresponding **radio and X-ray synchrotron losses**. Most extragalactic *γ*-ray sources, therefore, turn out to be AGNs, mainly of the **BLAZAR** family. X-ray absorption may however affect **detection of the counterpart**.



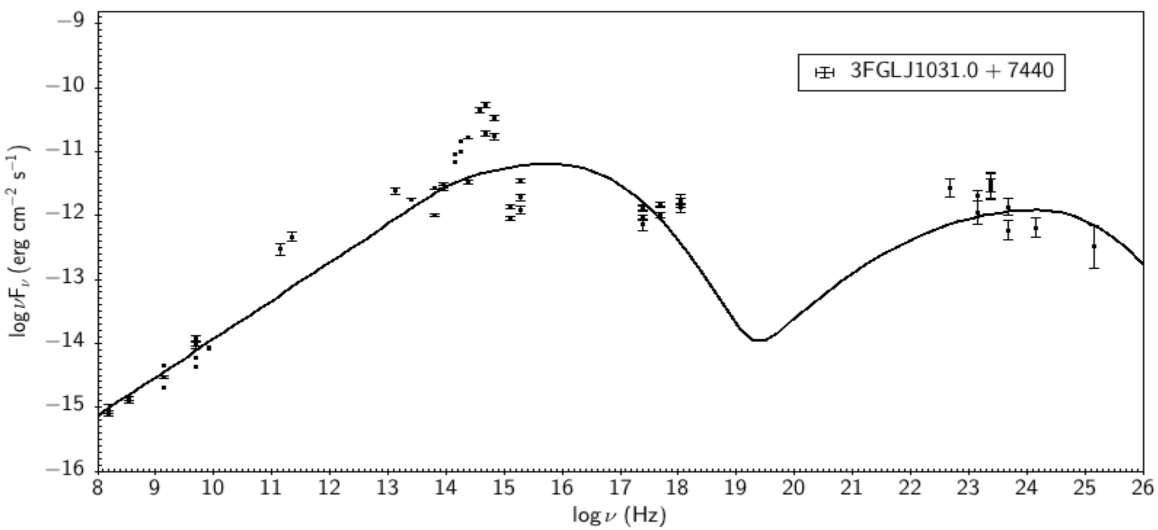


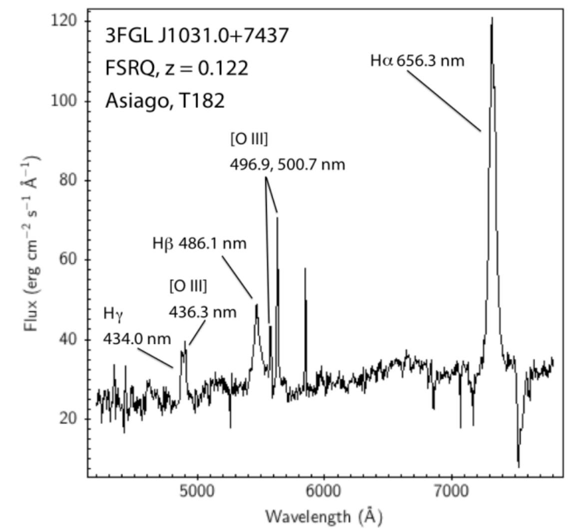


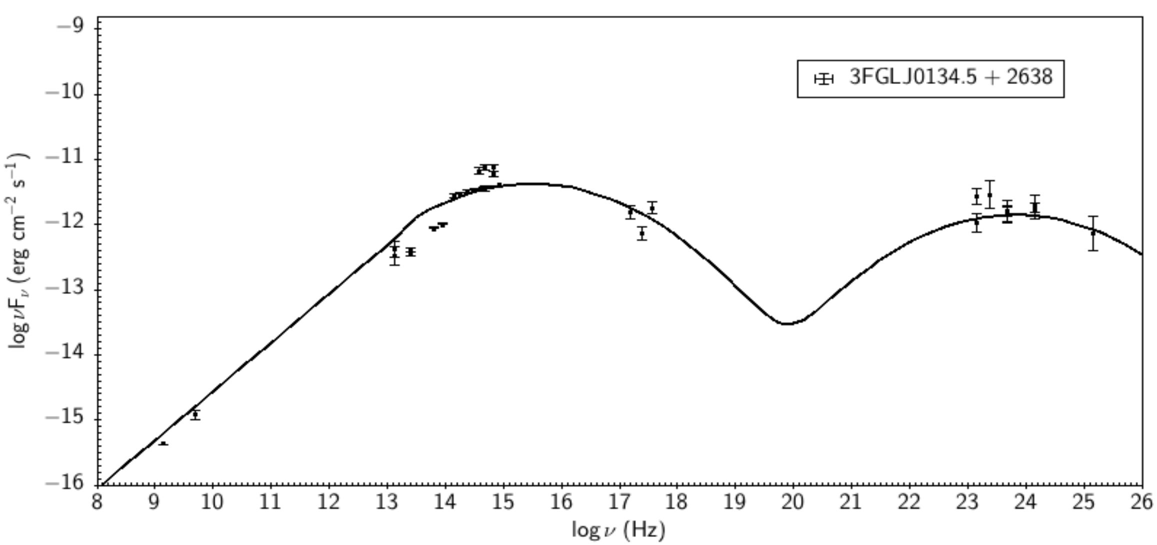
La Mura et al. (2017, EPJ D, 71, 59)

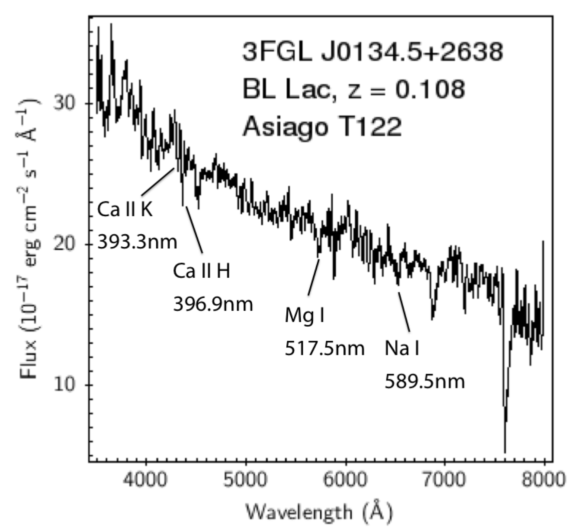
Multiple frequency data and spectral classification

Adopting multiple-frequency association techniques, we are able to identify counterparts to poorly constrained high energy sources. The technique turns out to be particularly effective in the case of sources with powerful synchrotron emission (**BLAZARs** and other types of AGNs with relativistic jets). The synchrotron dominance correlates with the characteristics of the optical counterpart spectrum.





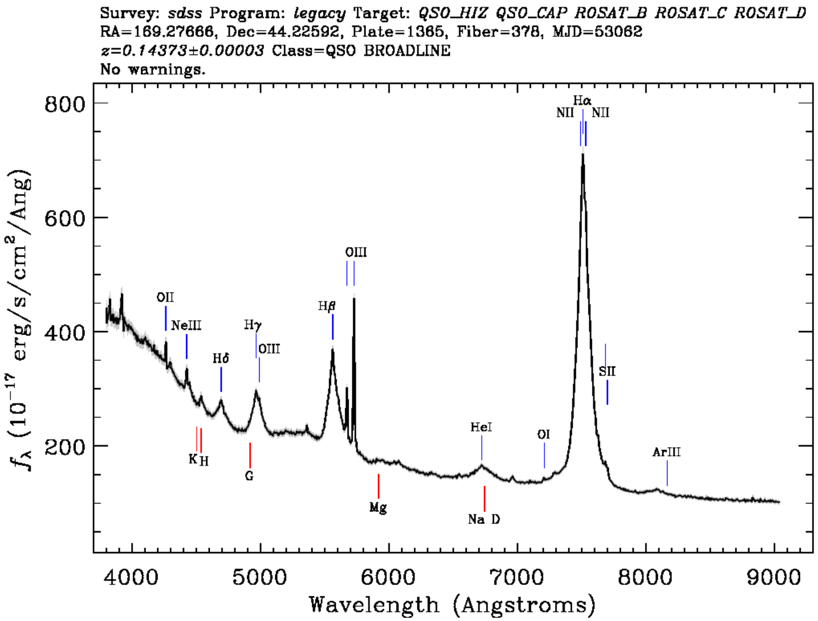




La Mura et al. (2015, JApA, 36, 447)

Implications on the structure of the central source

The study of spectroscopic information in various frequency domains can place important constraints on the unresolved structures that surround an AGN central engine. The combination of X-ray spectra with the properties of optical emission lines can lead to map the distribution of the gas around the central ionizing radiation source.



La Mura et al. (2013, AdSpR, 54, 1382)

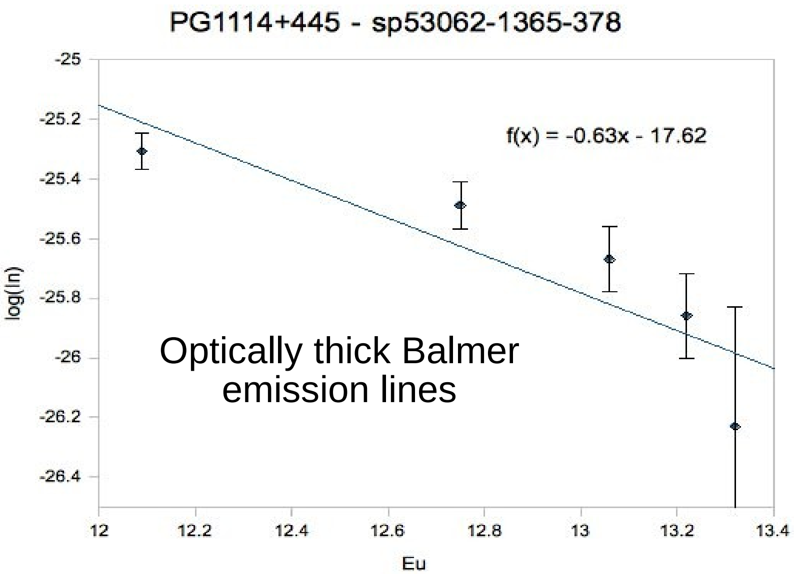
If we consider the transfer equation for Balmer line photons:

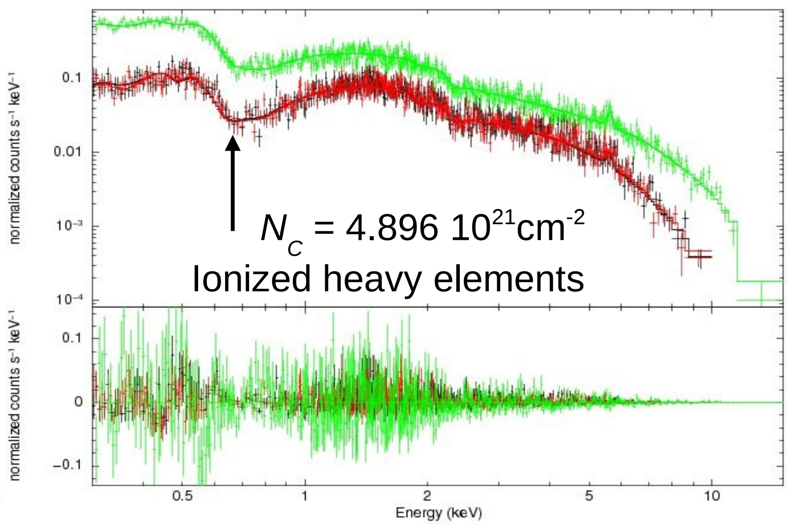
$$I_\nu(\tau_\nu=0)=I_\nu^0\exp(-\tau_\nu')+\int_0^{\tau_\nu'} S_\nu(\tau_\nu)\exp(-\tau_\nu)\,d\tau_\nu$$

where:

$$\tau_\nu'=r'\sigma_2 N_H(2)$$

the occurrence of high optical depth in the Balmer series becomes suggestive of an **overpopulation of excited levels**, which is possible in **recombining plasma**.

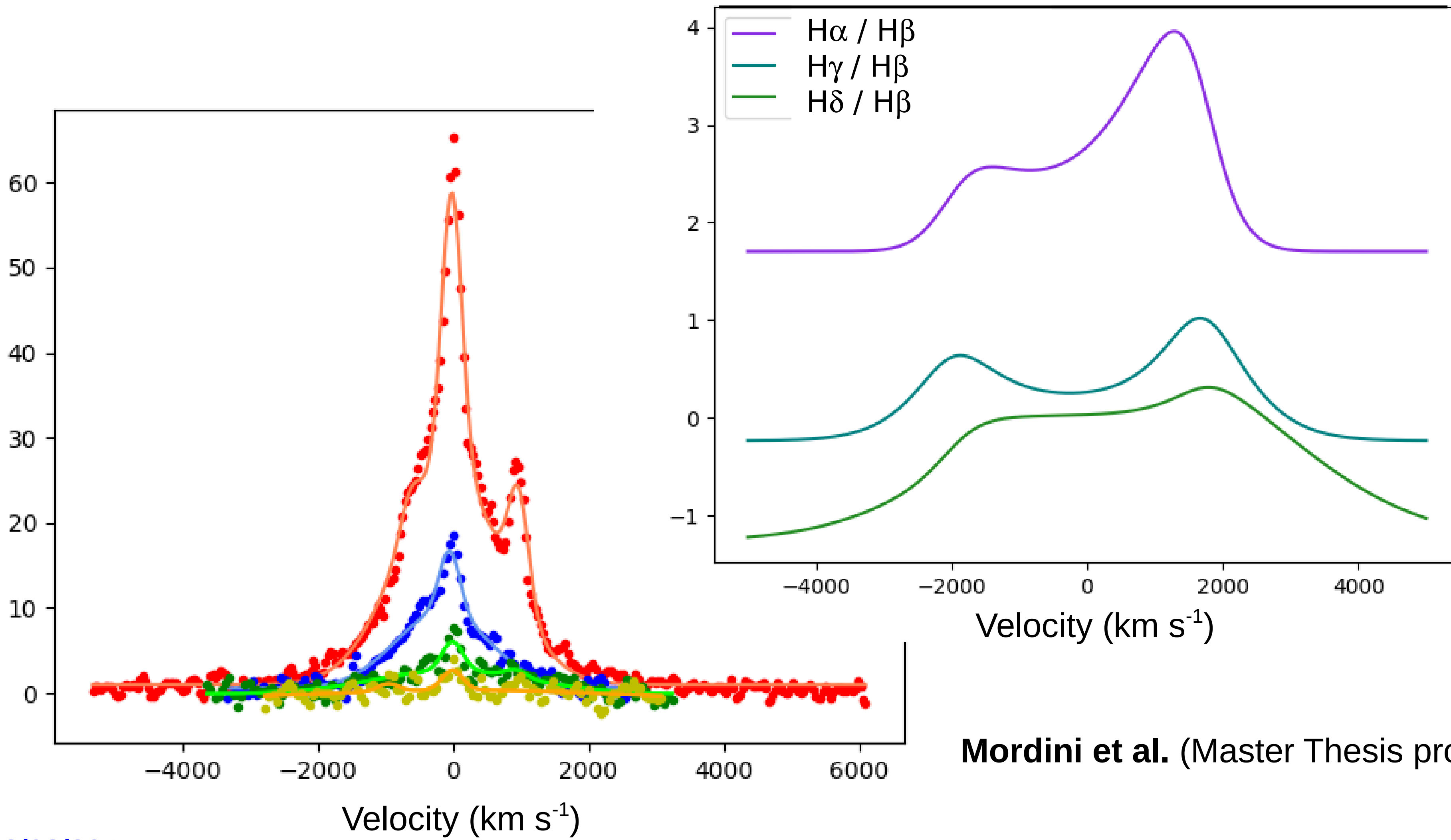




PG1114+445
the soft X-ray spectrum correspondingly shows evidence of absorption from ionized plasma. The same material might be responsible for the Balmer line optical depth, if located in the outer part of the Broad Line Region

More on optical depth effects

We can easily develop fast models to reproduce rather complex line profiles and adopt them to isolate the broad component of recombination lines in samples of type 1 AGNs. If we look at the Balmer line intensity ratios, as a function of velocity with respect the galaxy reference frame, we commonly detect non trivial ratio profiles, which are sometimes consistent with the signature of a flattened rotating system.



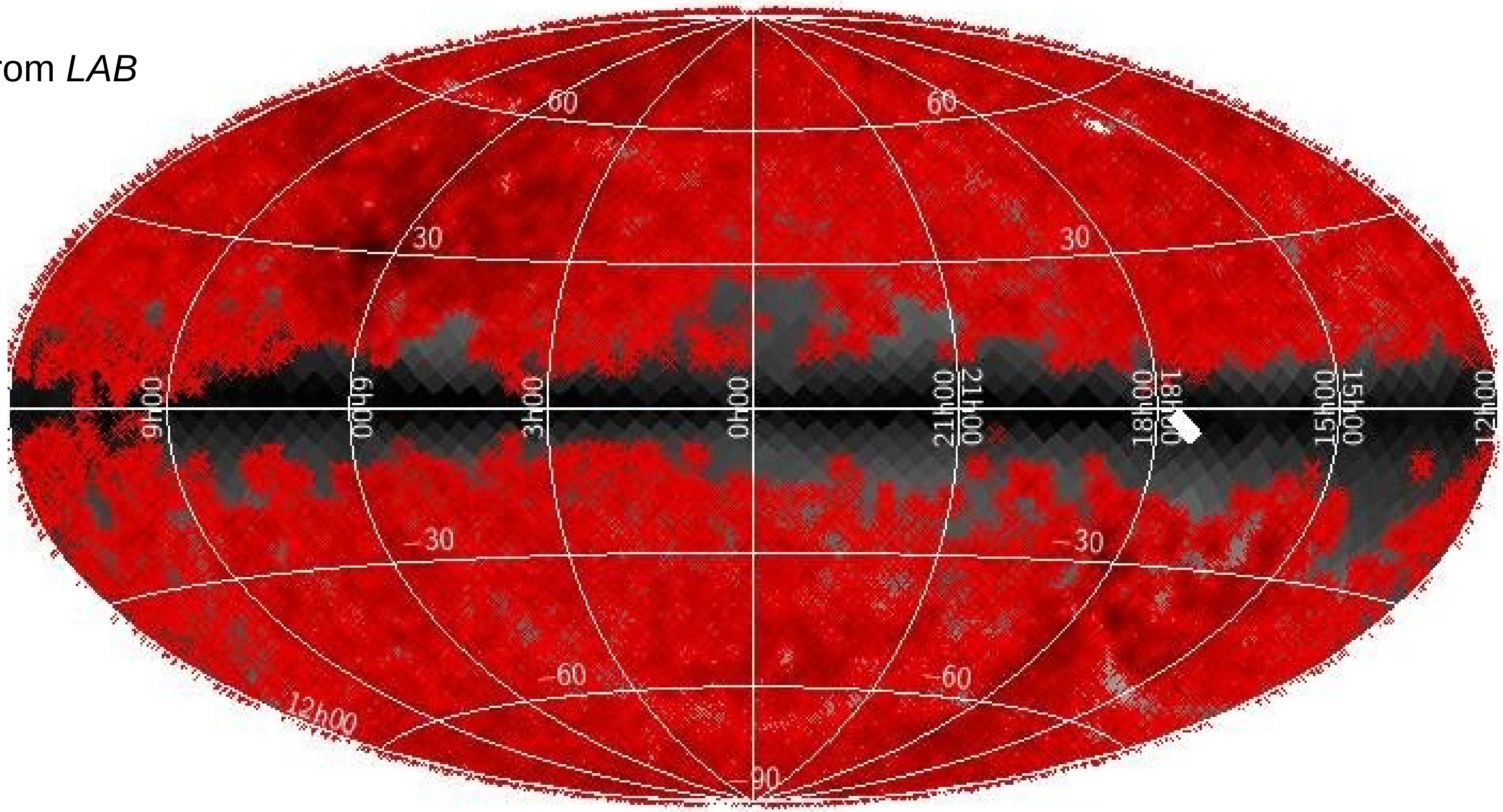
Mordini et al. (Master Thesis project)

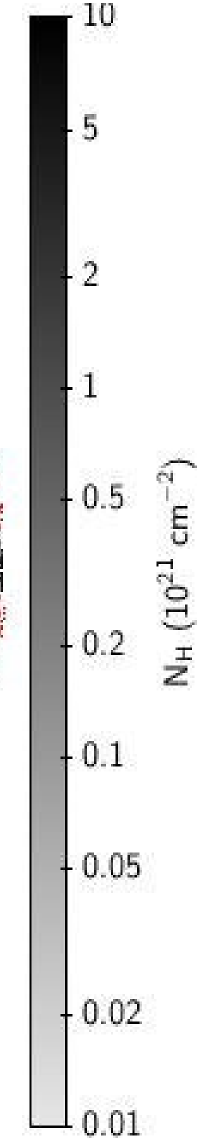
Multiple frequency sky maps

In order to overtake the limits of target selection from privileged, but **confined**, sky areas, we can use the extended AGN spectral energy coverage to build a nearly **all-sky list of sources** detected from IR to X-ray frequencies. **AGNs** are sought for on the basis of their **expected X-ray signal**, reported in the latest compilation of the ROSAT All Sky Survey (**Boller et al.**, 2016, A&A, 588, 103).

Combined map of sources detected by: ROSAT, GALEX, WISE
(with optical and 2MASS magnitudes)

N_H from *LAB*

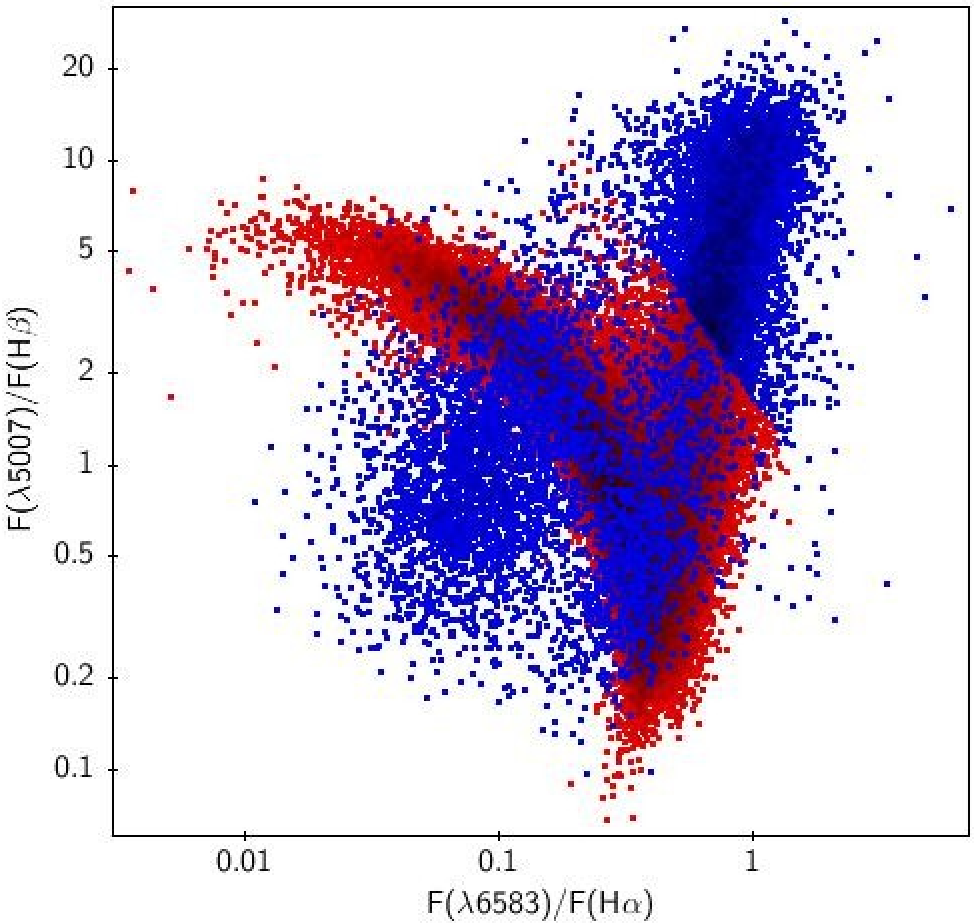




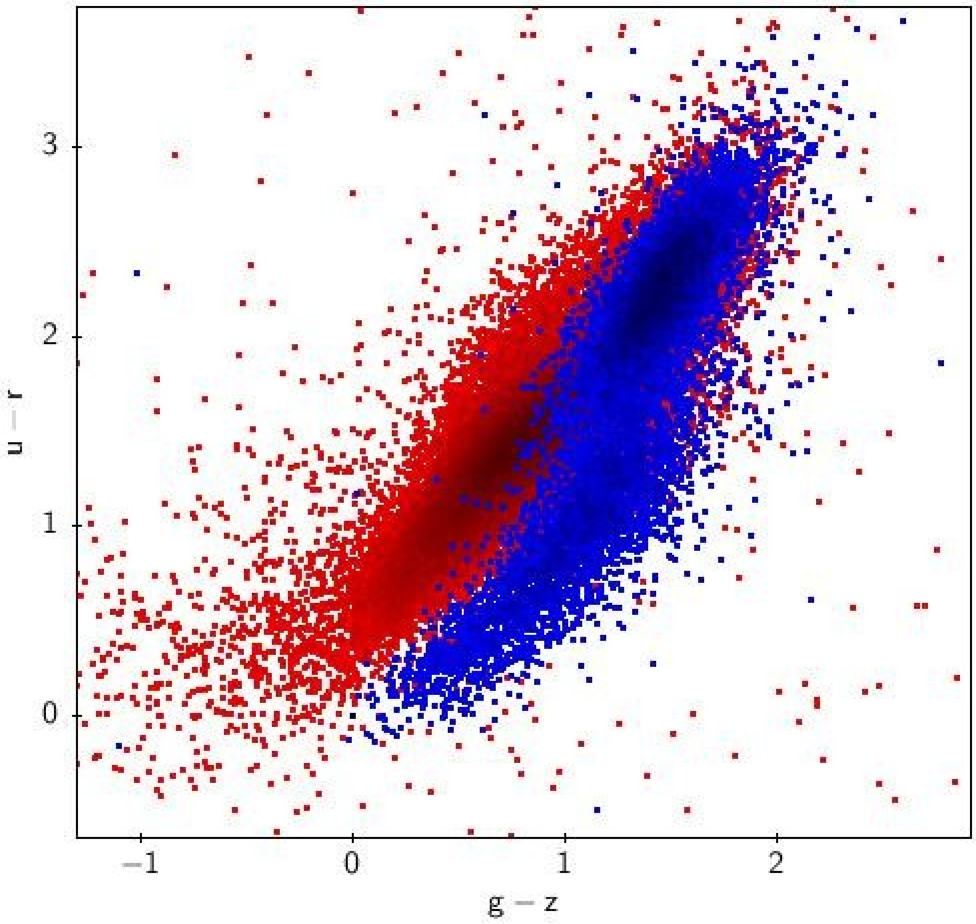
Bottle-neck: the Galactic plane

Classical vs. new source selection tools

Selection of large source samples leads back to classification problems that affect the possibility to send specific targets towards the most proper pipeline. The combination of slightly modified classic diagnostic tools, based on extensive spectroscopic and photometric analysis may help to solve the problem.



Classic BPT diagram, but for objects with both broad and narrow lines

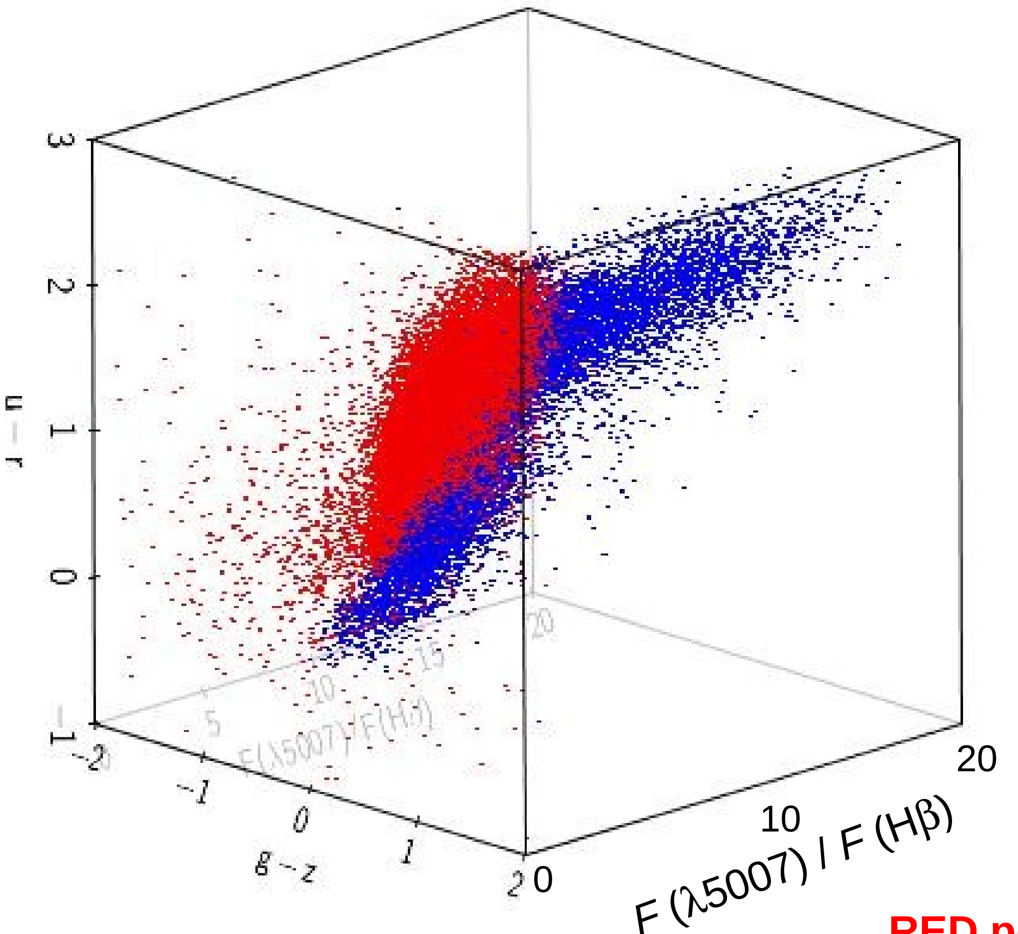


(u - r) vs. (g - z) color-color diagram for emission line objects in SDSS legacy survey

RED points: starburst / star-forming galaxies
BLUE points: QSOs and Seyfert galaxies

Putting all together

A closer look on how the spectroscopic and photometric diagnostic plots can work together is possible if we combine observations in a multi-dimensional parameter space. In addition to the use of diagnostic lines, wide band colours are particularly sensitive to the strong blue excess that we expect from sources with prominent broad recombination line profiles.



3D representation of the (u - r) vs. (g - z) colour-colour diagram, overlaid on the [O III] λ5007 / Hβ diagnostic line ratio.

When the ionizing radiation source of AGNs is **not directly visible**, we are able to distinguish its specific signature through the significant effects it has on the **intensity of narrow emission lines**. If the source is visible, on the contrary, the large contribution of the BLR to **the recombination lines** affects the observed line ratios, but the presence of a prominent **big blue bump** in the strongest broad line emitters still leads the sources to populate **a different region** of the parameter space.

RED points: starburst / star-forming galaxies
BLUE points: QSOs and Seyfert galaxies

Concluding remarks

- Multiple wavelength association is a promising technique to search for AGN candidates of different spectral types.
- SED models result in a good agreement with the expectations of an unified model based on the idea of increased obscuration moving from type 1 to type 2 objects.
- Automatic procedures to select spectral features are needed to send target candidates towards the most proper modelling pipeline.
- In case of AGNs, the best general option appears to derive from a combination of photometric and spectroscopic indicators.
- Modelling of the broad component of emission lines, based on the conclusions derived from multiple frequency data, can help in constraining the geometry of the central structures.
- Rotation and flattening often appear to be consistent with the observed line profiles.