Optical spectroscopy of 3CR sources: accretion and jet launching in radio galaxies

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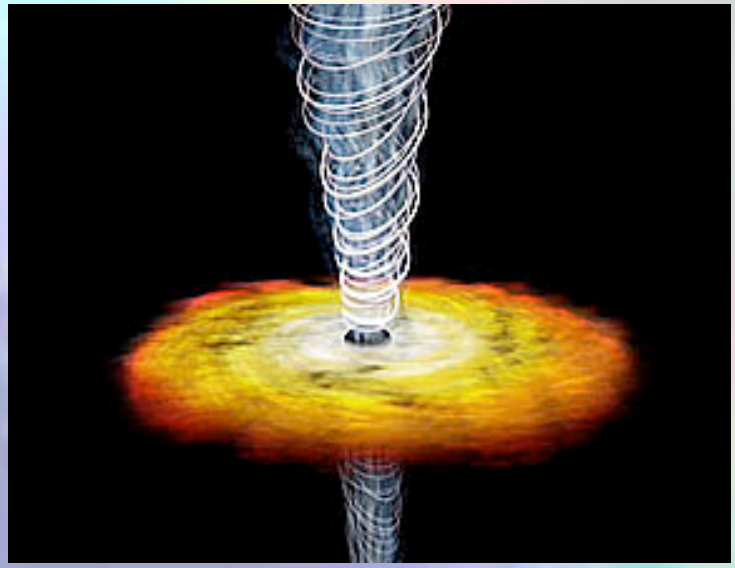
Como, 23 June 2009 *Accretion and ejection in AGN: a global view*

Accretion disk – jets relation

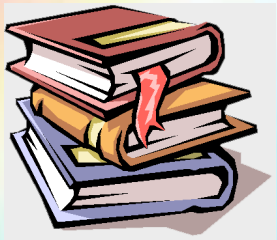
- Through the optical emission we can infer the properties of the accretion mechanism

- Through the radio core and extended emission we study the jets properties.



How are accretion properties and jets formation related?

An optical spectroscopic survey of 3CR radio-galaxies to explore the link between emission lines and radio properties.

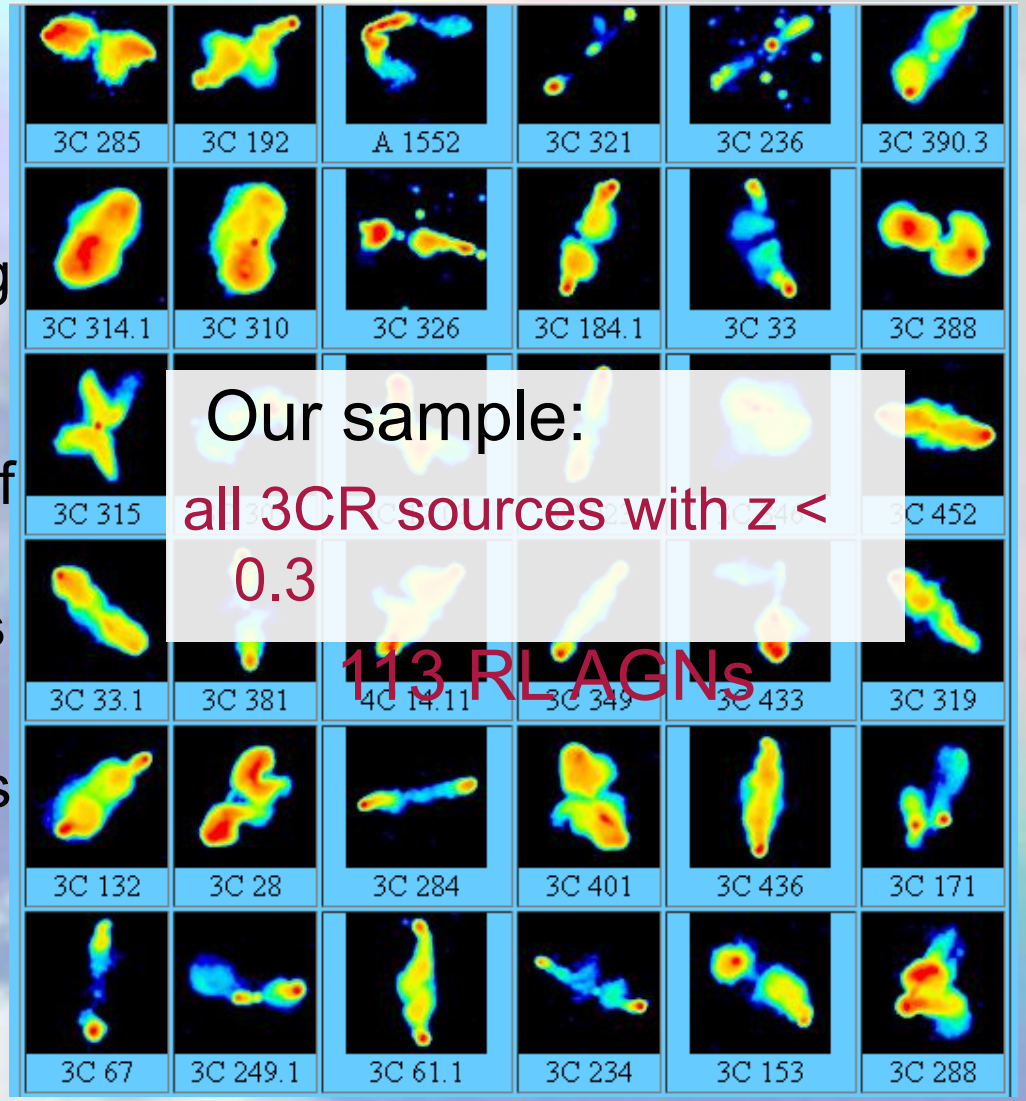


3CR Catalogue

- Third (revised) Cambridge Catalogue (**3CR**) of radio sources (Bennett 1962) using extended emission at **178 MHz**
- Survey of all sources North of -05 degrees with a F_r > 9Jy:

unbiased and homogeneous

- Largely used Catalogue
- Huge set of multiwavelengths observations (HST, Chandra, Spitzer, VLA...)
- **… but sparse and incomplete optical spectroscopy!**



Our sample:

all 3CR sources with z < 0.3

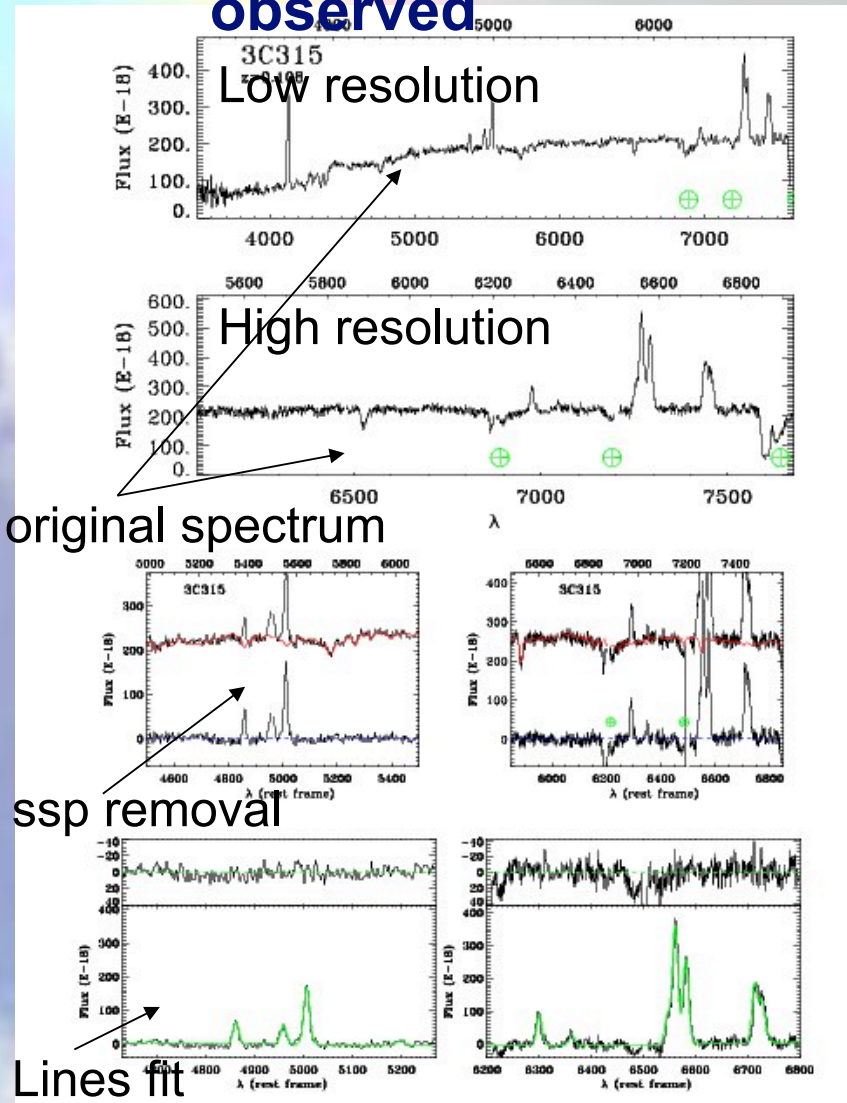
113 RL AGNs

3CR spectra

TELESCOPIO NAZIONALE GALILEO

- Observational strategy:
  - 3.58 m TNG – DOLORES – 2" slit
  - LOW and HIGH resolution grisms
    - Low: 3000-8000 Å, res. 20 Å
    - High : 6200-7800 (or 7300-8900) - res. 4 Å
    - Exposure time depending on source redshift (Low 500 - 1000 sec, High= 2x Low)
- Modeling:
  - Extraction of a 2" x 2" region (~ 8 Kpc for z = 0.3)
  - Host emission removal using SSP Bruzual & Charlot 03 library
  - SPECFIT (emission line fit)

100 3CR observed

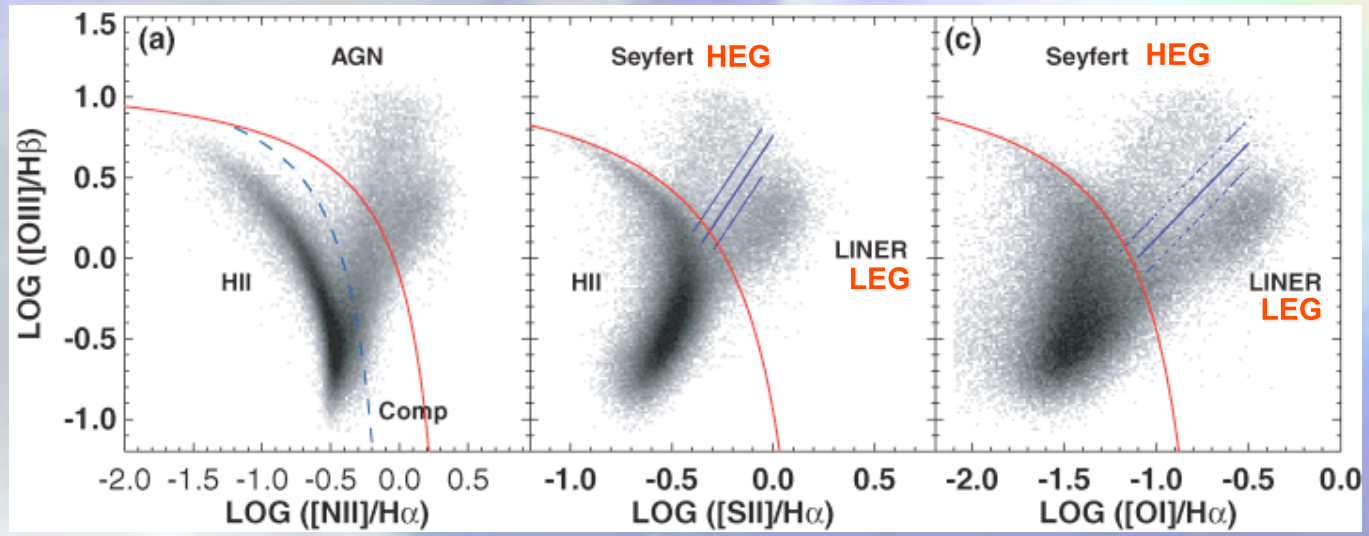


Data quality:

Hα and [N II] detected in all but 3 sources; all 6 key diagnostic lines are measurable in 75% of the RG.

Spetroscopic Diagnostic Diagrams

- They are formed by pairs of observed line ratios
- They reveal information on the ionizing radiation
- AGN can be separated into two sub-populations



SDSS emission line galaxies (~ 85000) Kewley et al 2006 : (mostly) radio quiet AGNs (Seyferts, LINERs) and starbursts galaxies.

How radio-loud AGN behave?

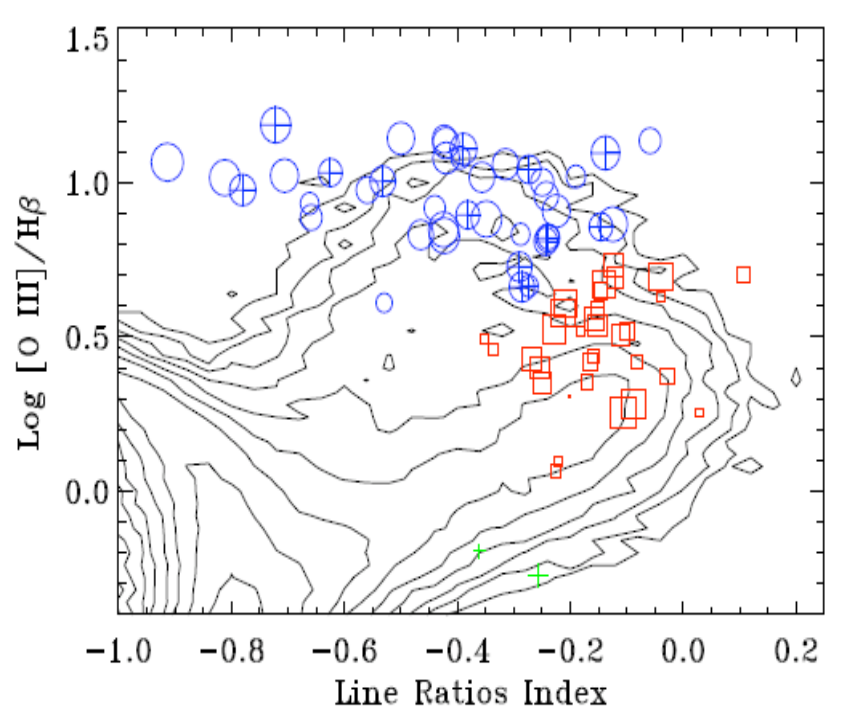
New ionization indicators

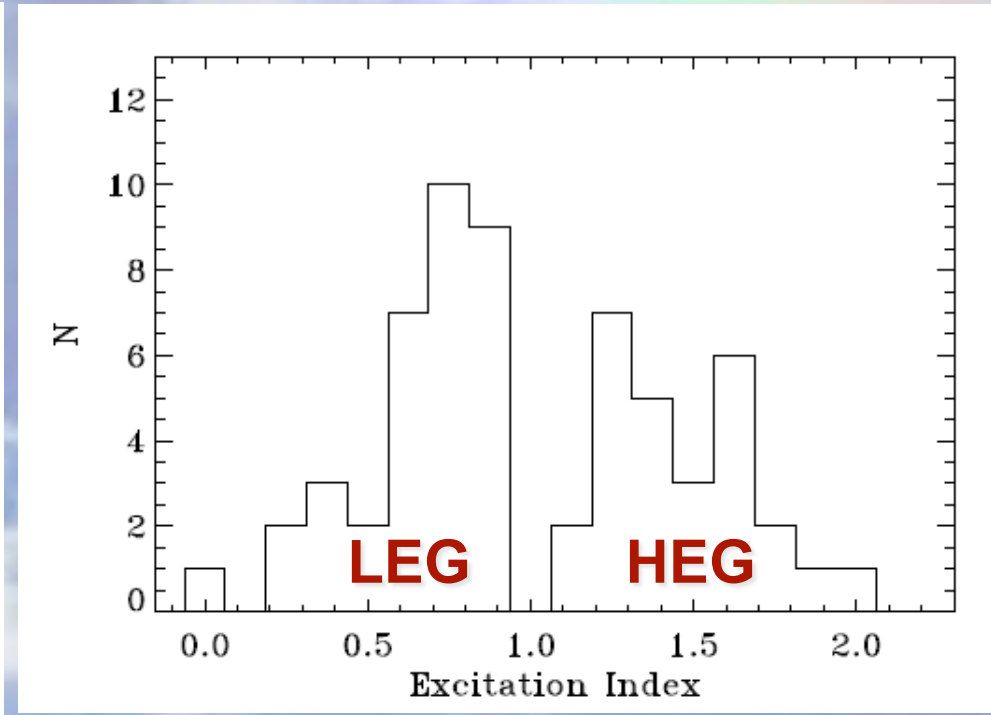
Line ratios index: average of the line ratios used for the DD and more stable than individual ratios.

Line Ratios Index LRI = ([NII]/Hα+[OI]/Hα+[SII]/Hα) /3

Excitation index: E.I. = [O III]/Hβ – LRI

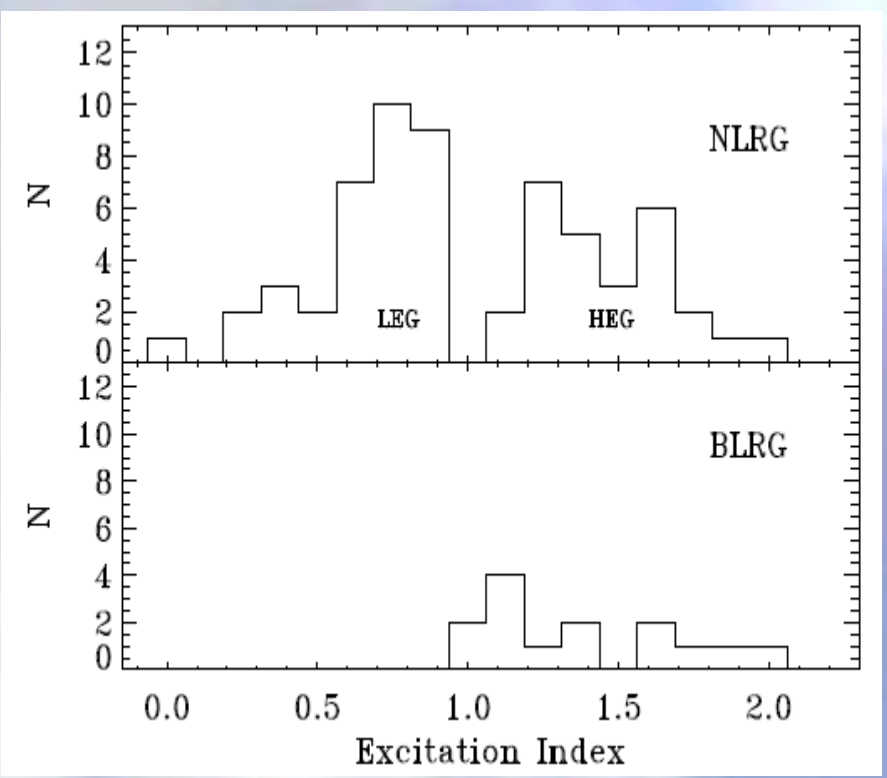
A bimodal distribution of E.I.: two classes LEG and HEG



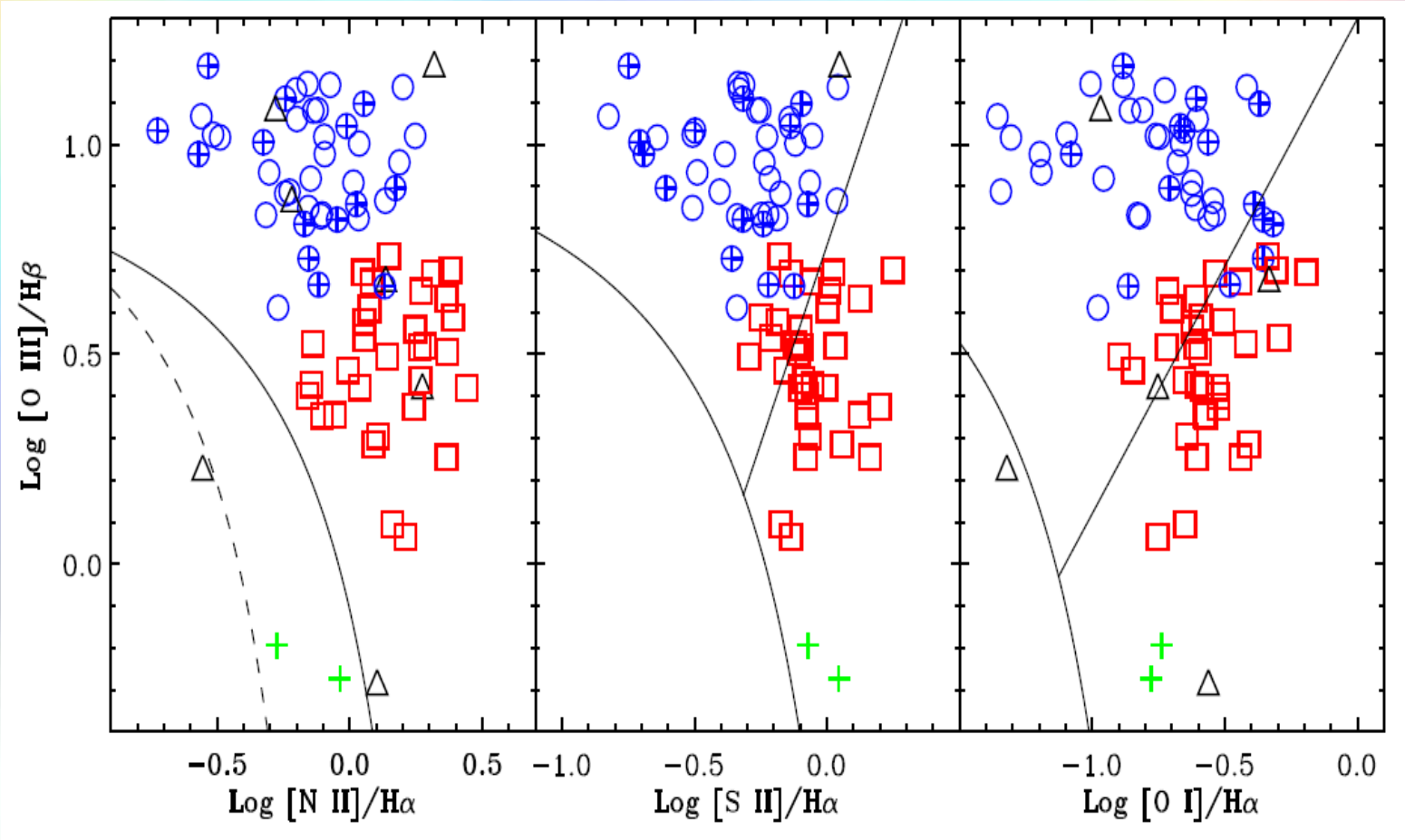


Broad Line Objects

17 objects show broad lines in their spectra. They are all HEG from the point of view of their narrow emission line ratios



Diagnostic Diagrams

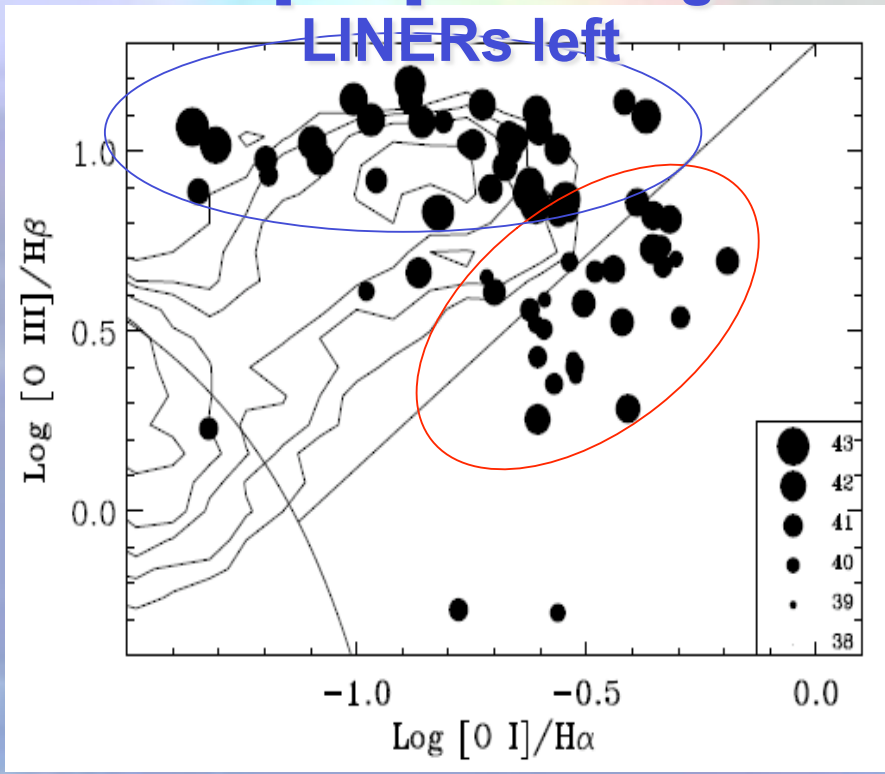


Good correspondence between E.I. and standard diagrams

RQ (SDSS) vs RL (3C) AGNs

- 3CR overlap onto SDSS but with extreme ratios
- The separation between LEG and HEG shows an upward scatter by 0.2 dex w.r.t. LINER/Seyfert
- But: the line luminosity of 3CR sources is much higher (about 30 times) than SDSS

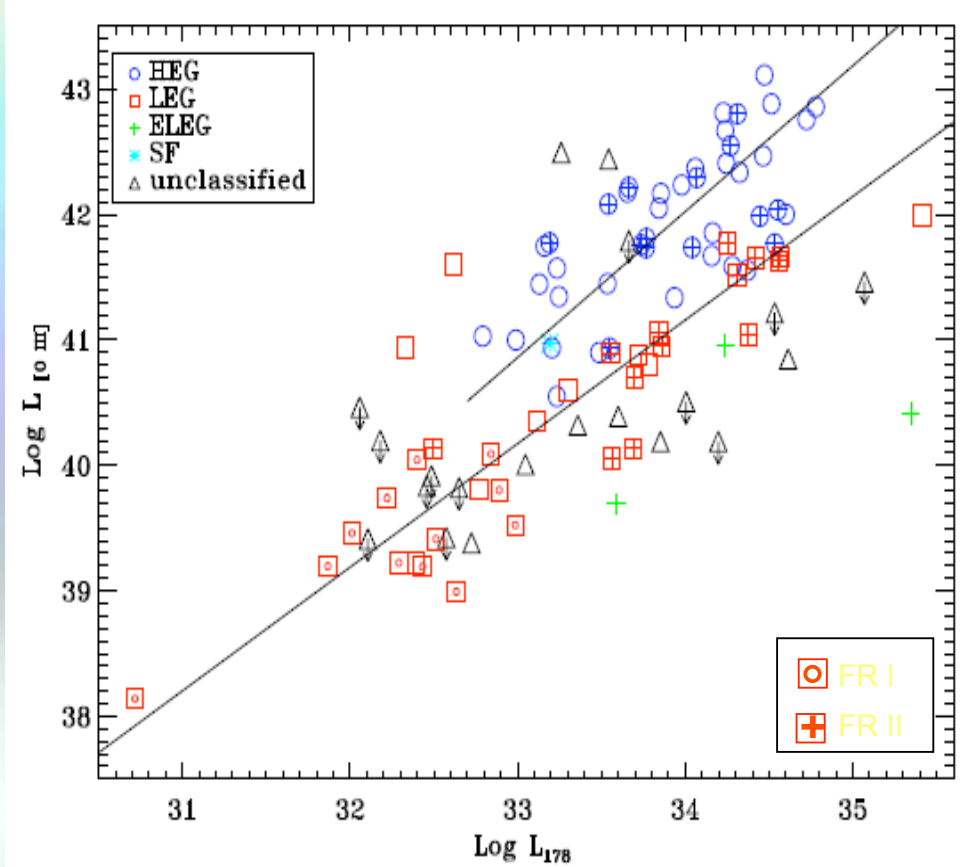
Comparison of RL and RQ only above L[O III] > 10^{40} erg/s: no LINERs left



Probably not genuine differences between RL and RQ

Optical – radio correlation

All HEG are associated with FRII radio-galaxies
LEG are of both FRI and FRII type



Two different correlations for LEG and HEG:

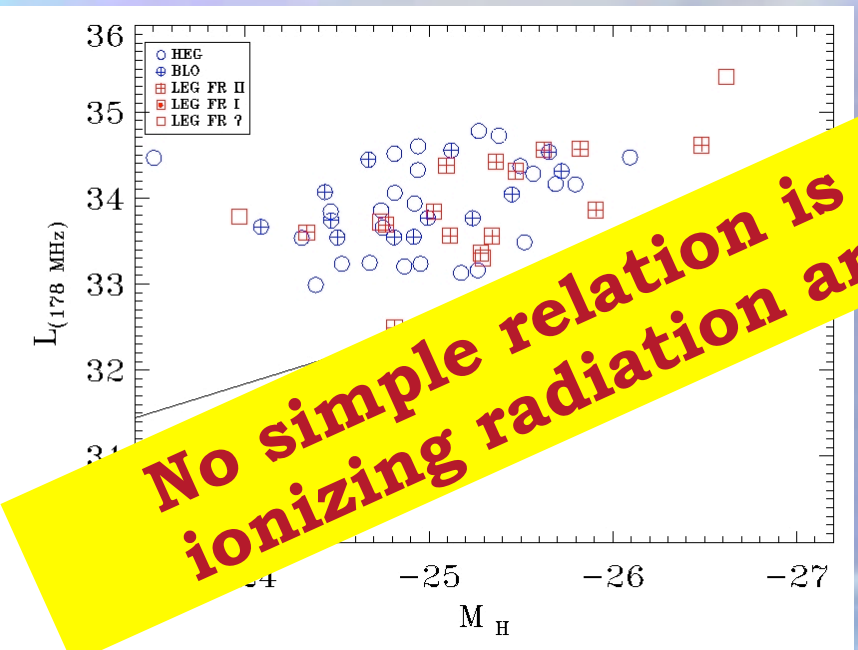
- they differ by ~1 order of magnitude
- they have similar slopes (~ 1)
- both extend up to the highest level of radio emission
- only LEG below 6.3 10^{32} W/Hz radio power
- FRII LEG are indistinguishable in radio from FRII HEG (same morphology, same radio core).

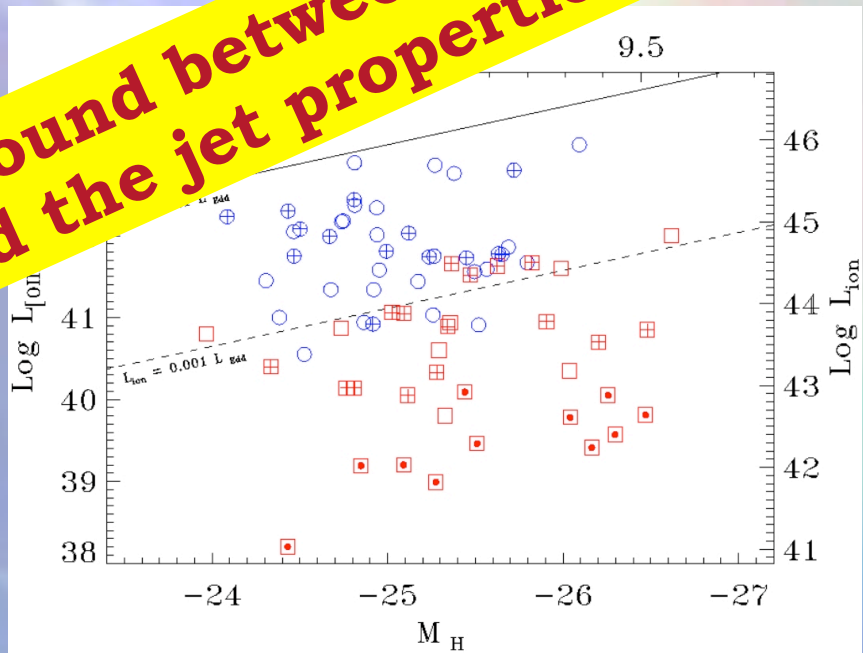
Are there 2 “different” levels of ionizing continua
at the same level of jet power?

Host galaxy – AGN connection

- Ledlow & Owen (1996) found that FRI and FRII are separated when comparing the host galaxy magnitude and the extended radio luminosity.
- Ghisellini & Celotti (2001) found a connection between the separation and the accretion rate, related to the nuclear ionizing luminosity.

No simple relation is found between the ionizing radiation and the jet properties





LEG/FRII and HEG are completely mixed!

LEG and HEG separate along a line corresponding to a constant value of the ratio $L_{ion}/L_{Edd} \sim 10^{-3}$.

A possible interpretation

HEG

- High excitation spectra
- High ionizing luminosity
- Broad lines (unless obscured)
- Only high radio power
- Obscuring tori
- Strong optical nuclei (unless obscured)
- Recent star formation (e.g. Baldi et al. 2009).
- Powered by cold gas (??)

LEG

- Low excitation spectra
- Low ionizing luminosity
- No broad lines
- Both low and high radio power
- No obscuring tori (??)
- Faint optical nuclei (Chiaberge et al 2002)
- No evidence for recent star formation.
- Powered by hot gas (coronal) accretion (Allen et al. 2006).

LEG only accrete hot gas (~10^7 K)…

… no "cold" structures, as observed.

No molecular gas to form tori and high T prevents the BLR formation.

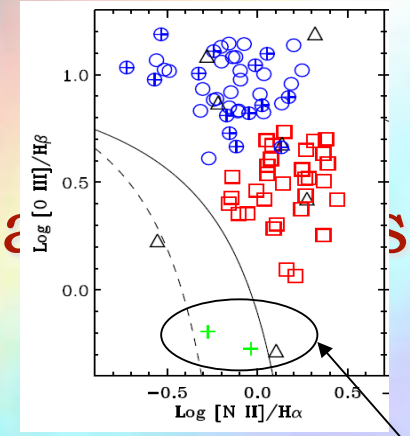
Hotter disks (?)

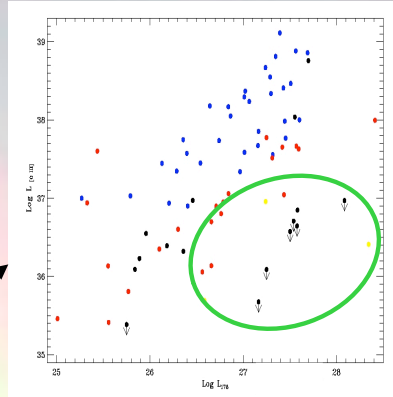
Fewer ionizing photons, lower line excitation (!), reduced emission in IR/ optical/UV, as observed.

Does jet launching depend only on accretion rate and not on initial T?

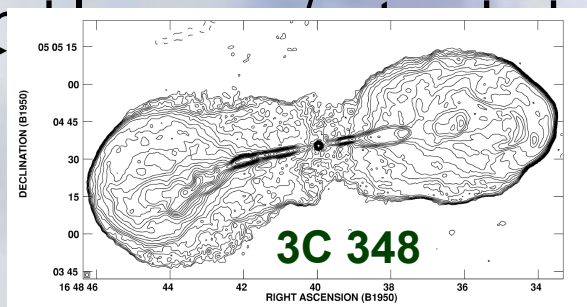
ELEG AGNs

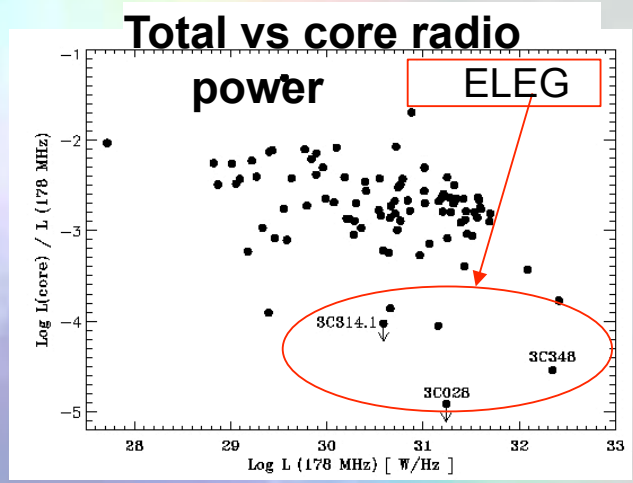
a ss: extreme low excitation





- very low [OIII]/Hβ ratio
- weak emission lines (WRT radio emission)
- weak radio core ar
  ratio
- FRII morphology





Drop of ionizing photons → weaker lines, especially [OIII]; while extended radio still unchanged

Idea: nuclear activity switched off → we observe cooling NLR → relic radio galaxies

Transient RG from FRII to FRI?

Conclusions

- We analysed optical spectra of 100 3CR radio sources with z<0.3.
- The sample is composed by two main spectroscopic sub-populations. 46 sources are HEG (of which 16 BLO), 37 LEG, 3 ELEG and 17 unclassified
- All BLO have HEG emission line ratios, all HEG are associated with FRII
- LEG are of both FRI and FRII type
- HEG are 10 times brighter than LEG in [OIII] at equal radio power.
- LEG show a lower level of line and nuclear luminosities, but they can be associated to the most powerful FRII radio-sources of the sample.

→ **Are the processes of accretion and the jet launching decoupled? (BZ)**

→ **Hot accretion flows at high rate (do they exist?) could produce powerful RG with reduced radiative output, e.g. high luminosity FRII/LEG.**

→ A new spectroscopic class of Extremely Low Excitation Galaxies is found. They are interpreted as relic radio-galaxies. Are they FRII to FRI transient?