The N V/C IV ratio in high redshift radio galaxies

Collaborators

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The programme

- ❏ To observe the early evolutionary phases of objects destined to become the giant ellipticals of today
- ❏ Select powerful radio galaxies — where the obscuration of the quasar by opaque material in its immediate vicinity acts as a ‘natural coronograph’
- ❏ At redshifts ($2 < z < 4$) corresponding the epoch of maximum quasar space density, the relationship between the formation of the AGN and the accumulation of its host galaxy can be studied
- ❏ Using the Keck spectropolarimeter, we have measured the restframe ultraviolet spectrum of a sample of 9 sources to high s/n
- ❏ We are using HST — WFPC 2 and NICMOS — for high resolution imaging
- ❏ We propose to observe the evolved stellar population and the forbidden line spectrum of the ISM using ISAAC on the VLT

Relevance to this meeting

The illumination of a large fraction of the host ISM by the quasar radiation field allows us to study its chemical composition in detail using permitted and forbidden emission lines from a low density gas.

This is a significant advantage over studies of the broad emission line region (BEL) in AGN and the broad absorption line (BAL) spectrum in its close vicinity.

Although these objects are faint (typically $22 < V < 24$), the lines can be measured with high s/n from 0.35 – 2.5 μm with large telescopes

The sample:

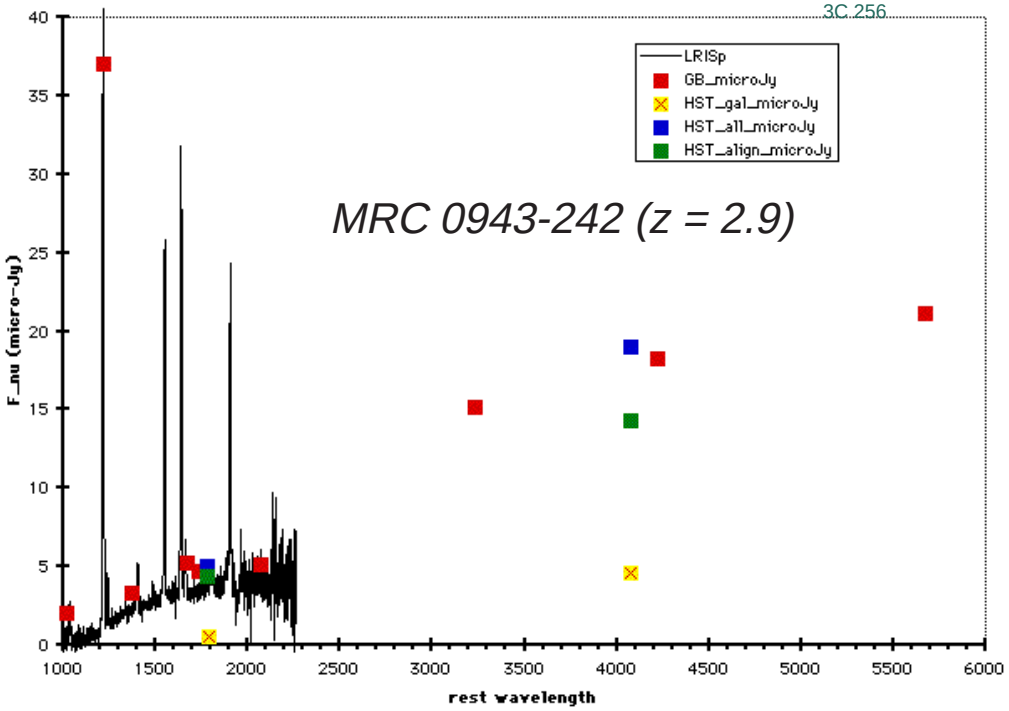
This sample is of powerful RG with z ~ 2.5 which allows us to study the strong UV emission lines from Lyα -> CIII], the UV continuum, resonance absorption lines and the 2200 Å dust feature — all in the optical band — and to straddle the 4000 Å break in the J -> K bands

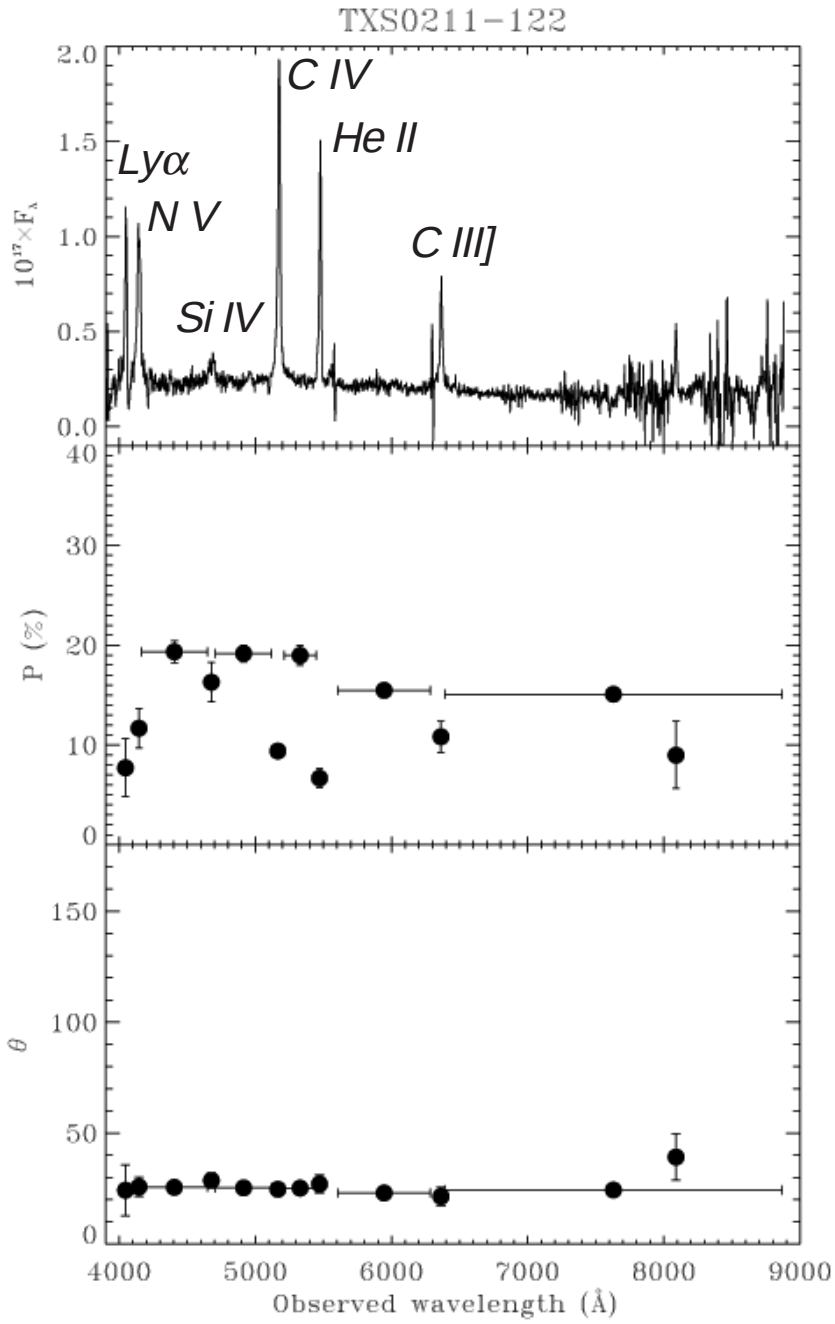
Our principal sample constists of nine objects with 2.3 < z < 3.6 and this is suplemented by four sources from the literature having similar quality data but extending the redshift range to 1.8 < z < 3.8

Object	z
4C+03.24	3.570
MRC 0943-242	2.9
USS 0828+193	2.572
4C+23.56a	2.482
B3 0731+438	2.429
4C-00.54	2.366
4C+48.48	2.343
TXS 0211-122	2.338
4C+40.36	2.265
4C+41.17	3.798
FSC10214+4724	2.2824
MRC 2025-218	2.63
3C 256	1.824

The data:

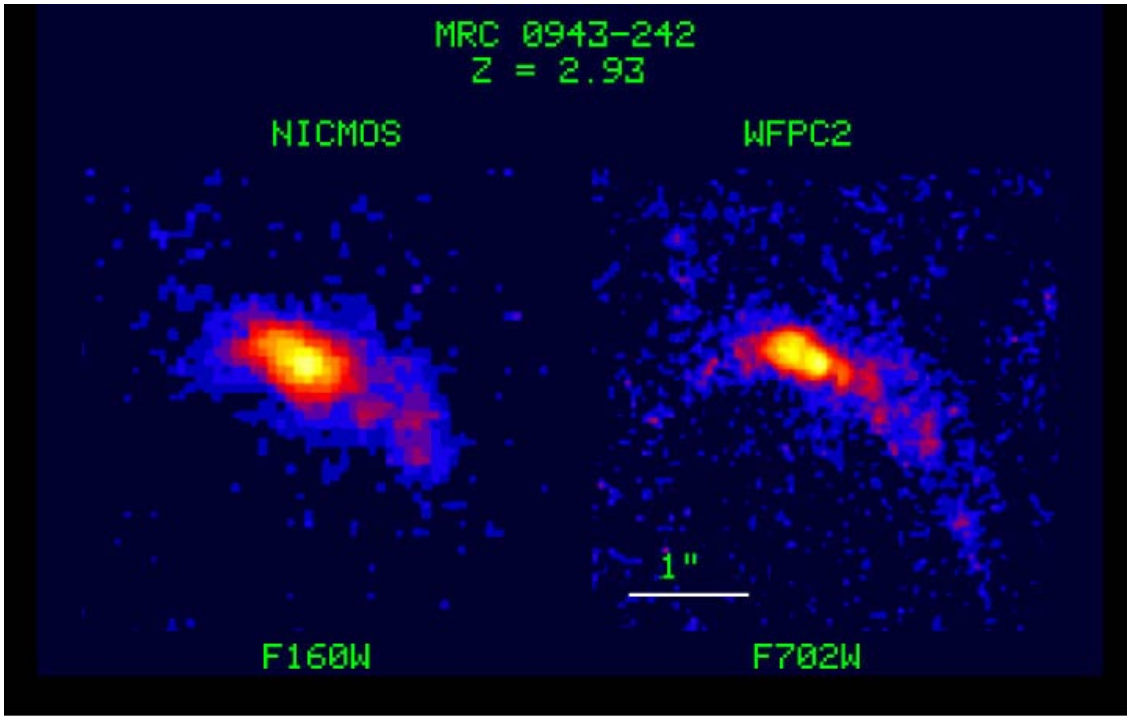
NICMOS and WFPC 2 images give us the morphology in the rest-frame optical and UV, and Keck (LRISp) spectropolarimetry gives us a very powerful tool for disassembling the UV spectral components



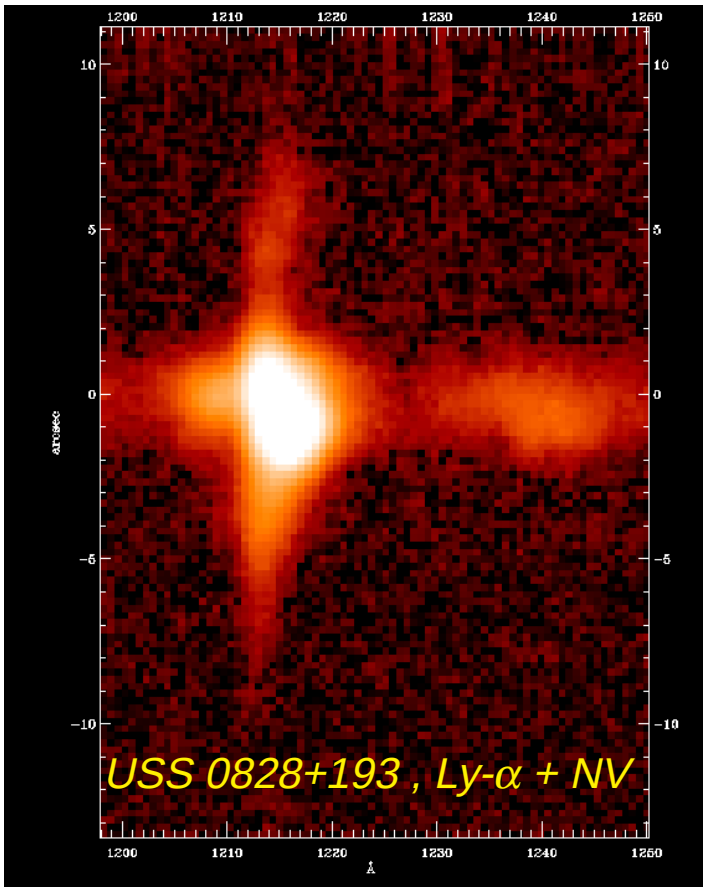


Spectropolarimetry

gives us line and continuum polarization with good s/n (up to ~20). The measured polarizations range from 0 to 20% integrated over the spatial structure.

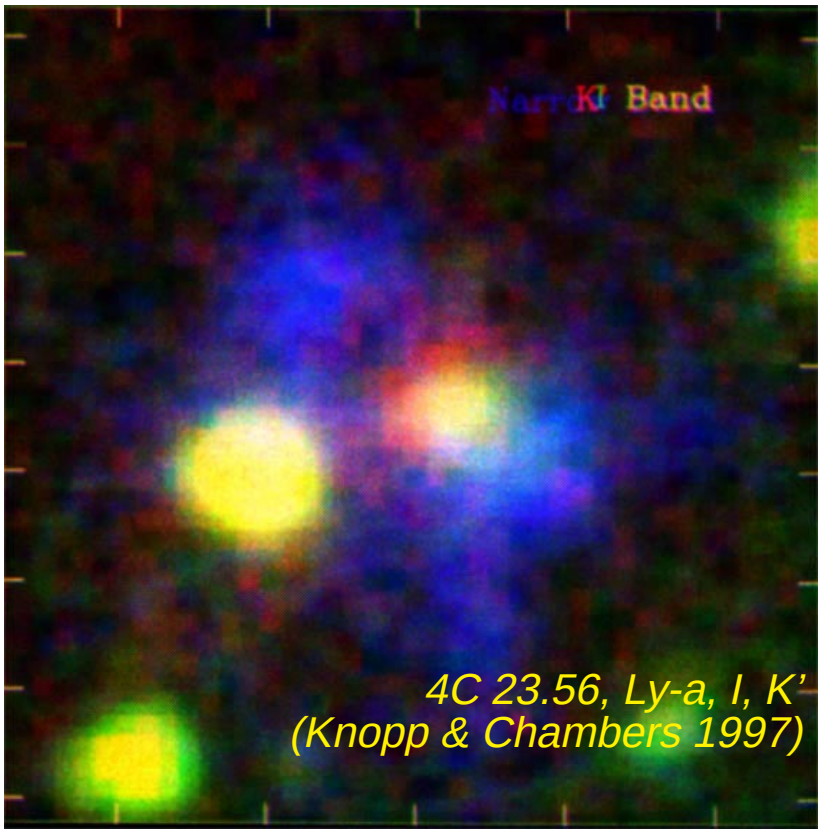


HST images and Keck long-slit spectra



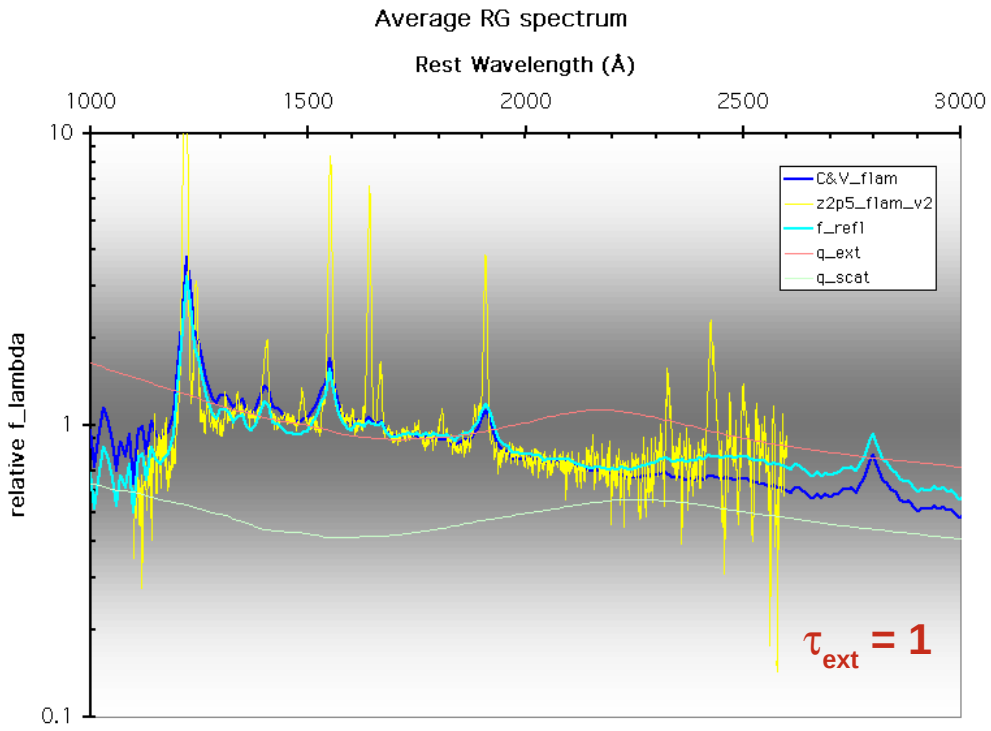
Principal results

- All sources show a strong ‘alignment effect’ between their UV and radio morphologies although the structures are complex. One case, 4C 23.56, shows a beautiful ‘ionization cone’ in Lyα. The brightest UV emission is extended and does not necessarily coincide with the nucleus (radio core)



- The continuum spectra are remarkably similar with a peak (in f_λ) near 1300Å and a dip near 2200Å

- Interstellar absorption lines are seen but in our data there is only marginal evidence for photospheric absorption lines from hot stars. Several sources show complex, spatially extended absoption structures at Lyα



The RG continuum and broad lines

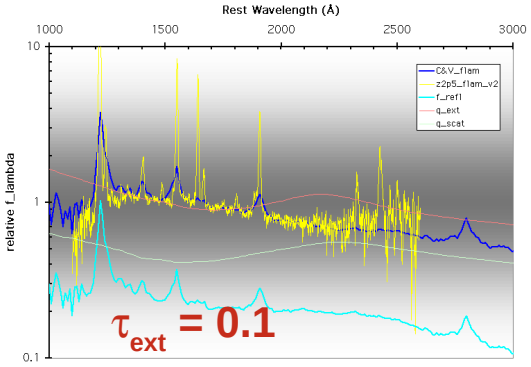
are modelled by reflecting an average quasar (eg. Cristiani & Vio 1990) in a 'dust scattering atmosphere'

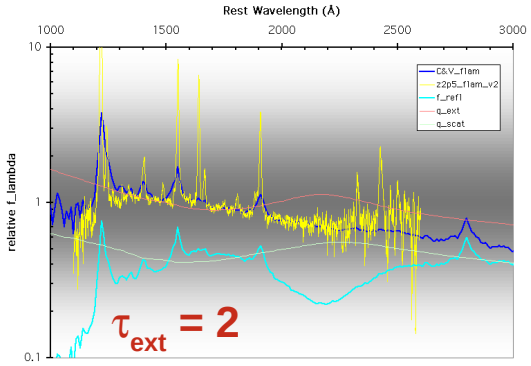
$f_{rg} \sim f_{qso}\ \tau_{scat}\ \exp(-\tau_{ext})$

Such a model naturally produces the maximum flux from the regions where $\tau \sim 1$

The fit is so good that there is little room for starlight in the UV!

<u>See poster by Vernet et al.</u>





- The emission lines are spatially extended (up to ~ 20 arcsec ~ 140kpc for Lyα) and show complex kinematic structures up to ± 2000 km/s

- The continuum linear polarization (measured just longward of Ly-α/NV) ranges from < 3% to > 20%. The E-vector is perpendicular to the UV extension (but not necessarily to the radio axis). HST images are needed to see this

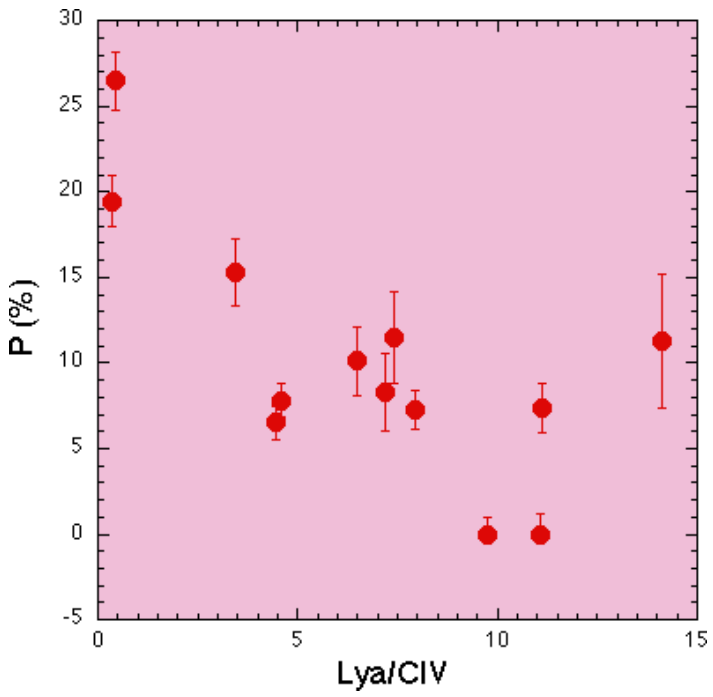
- The emission line spectra indicate a rather constant level of ionization with a small range in the observed CIII]/CIV and HeII/CIV line ratios.

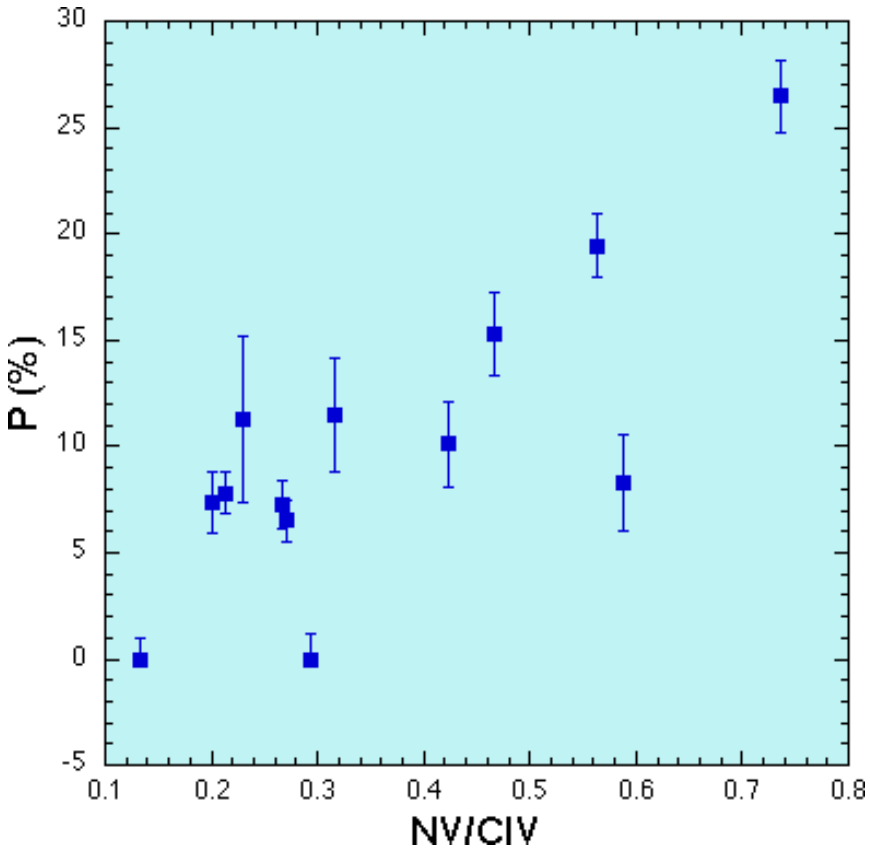
- Amongst the spatially integrated properties, the strongest correlations are observed to be:

    1) between continuum polarization (P) and the Lyα/CIV emission line ratio (anticorrelation)

    2) between P and the NV/CIV ratio

- The high redshift (z > 3) objects have relatively strong Lyα and weak NV





Interpretation of the P — NV/CIV diagram

Use the carbon/helium diagnostic diagrams (Villar-Martín, Tadhunter & Clark 1997 – using MAPPINGS) to establish the ionization mechanism and range of ionization parameter (U)

Note the similarity of the NV/CIV, NV/HeII diagram to the quasar BEL (Hamann & Ferland 1993). This argues that we are seeing a similar composition effects in the nuclei and the extended ISM at z > 2

The timescale for the chemical evolution resulting from a massive starburst in a deep potential well (0.1 – 1 Gyr) is much longer than the evolutionary timescale of the UV luminosity of the stars (10 Myr)

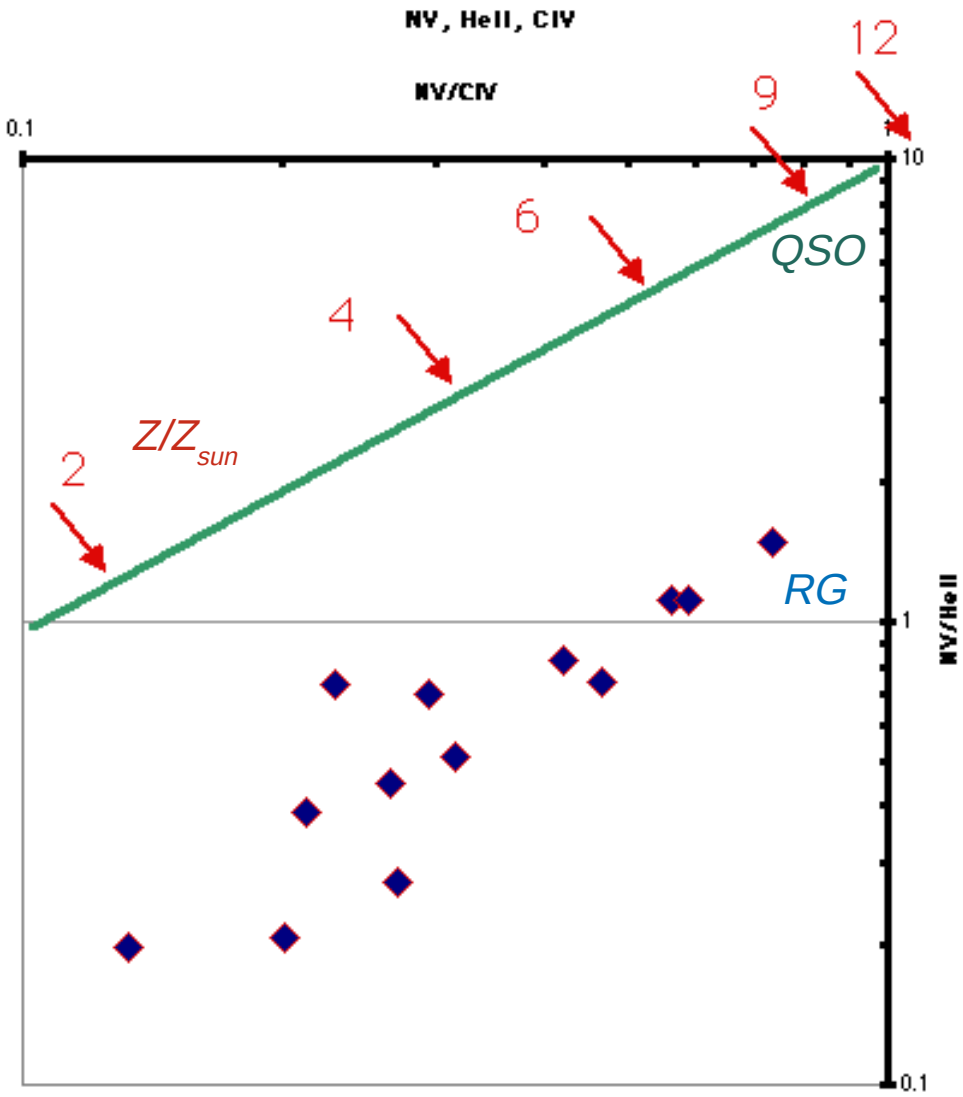
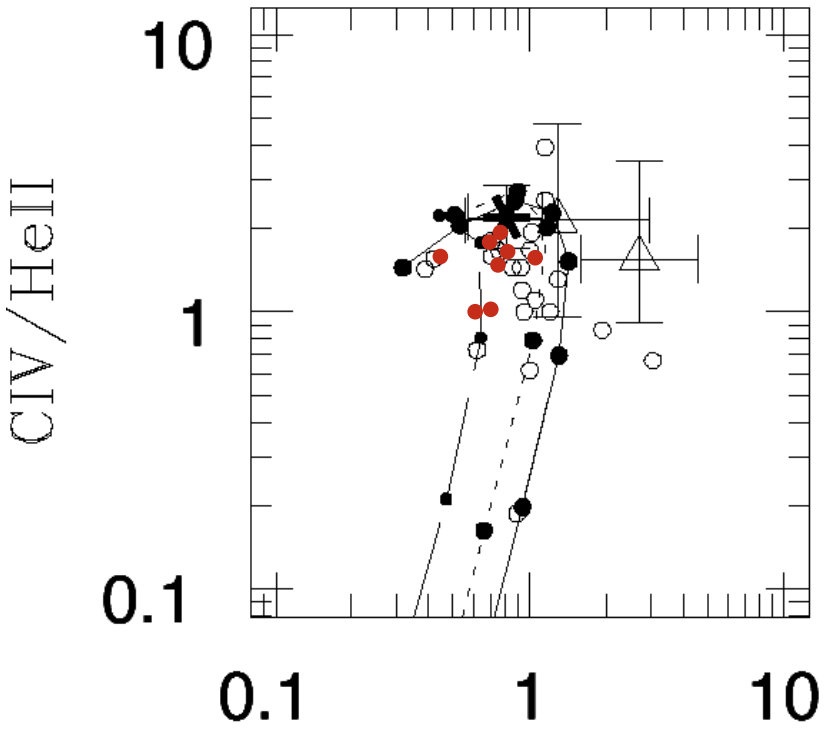


Diagram showing the position of the HzRG compared to the quasar BEL studied by Hamann & Ferland (1993) and modelled by super-solar metallicities using a rapid star formation enrichment model.

Note that the values if n and U are quite different for the BEL and the extended ISM

Helium/ Carbon diagnostic diagrams for the z ~ 2.5 radio galaxies (•)

(Villar-Martín et al. 1997)

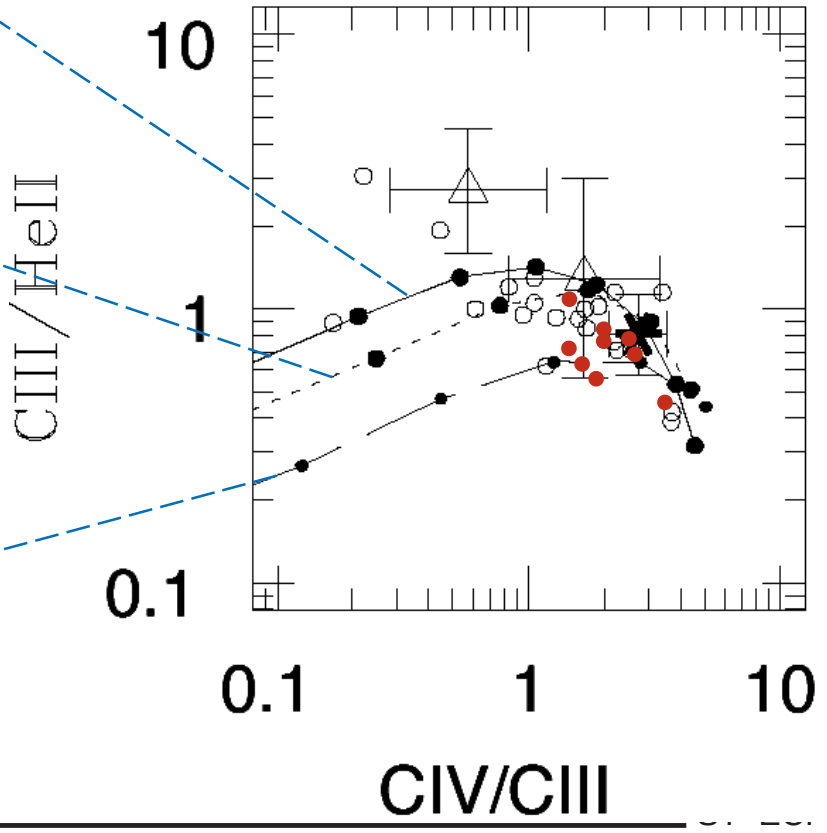


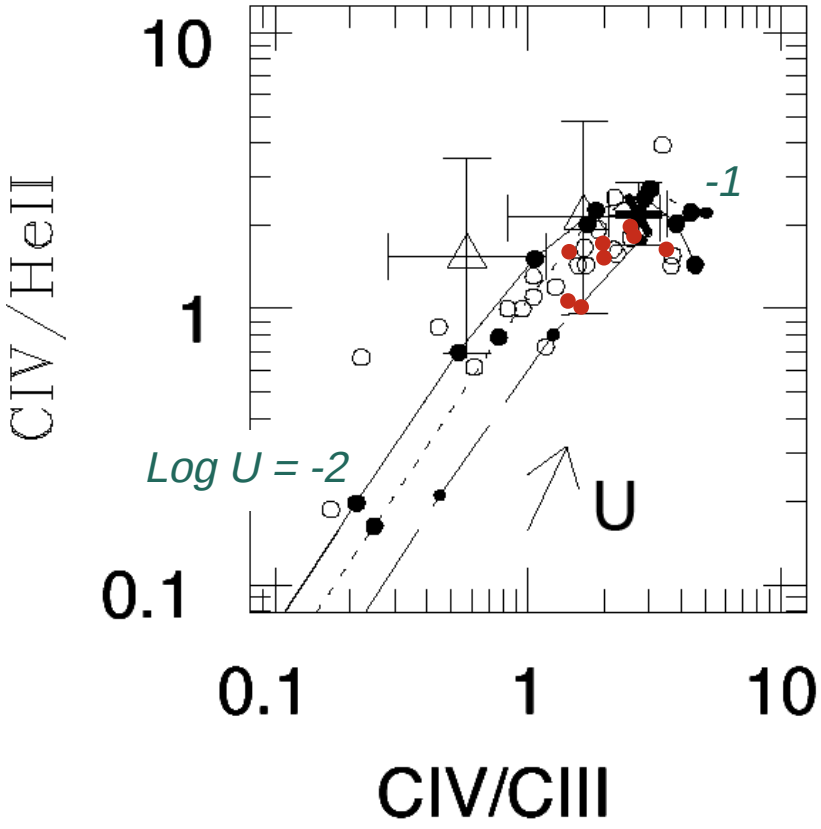
α = -1
Z_{sun}

α = -1.5
0.4 Z_{sun}

α = -1.5
Z_{sun}

valid for low z RG



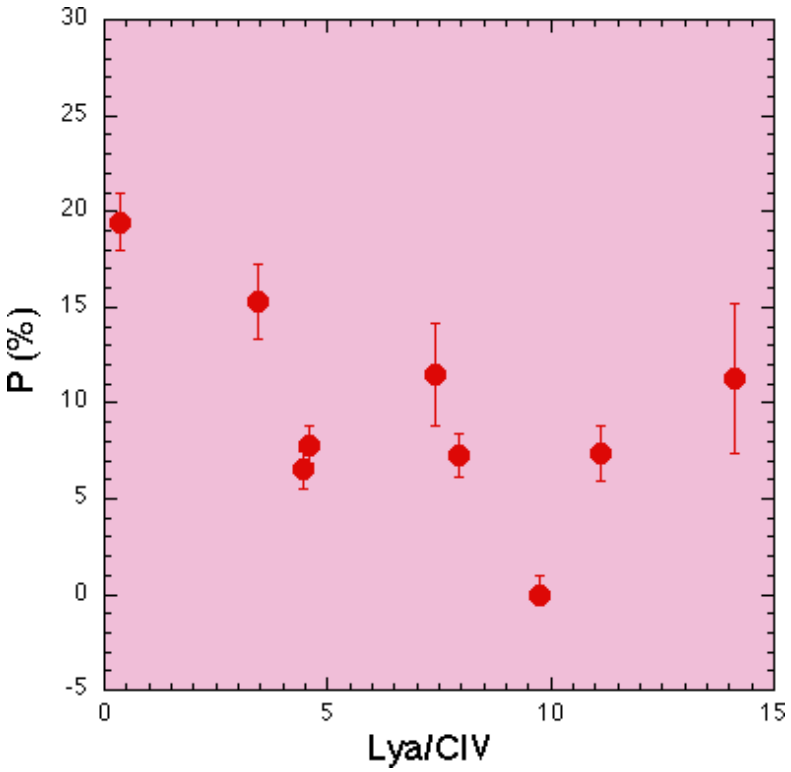


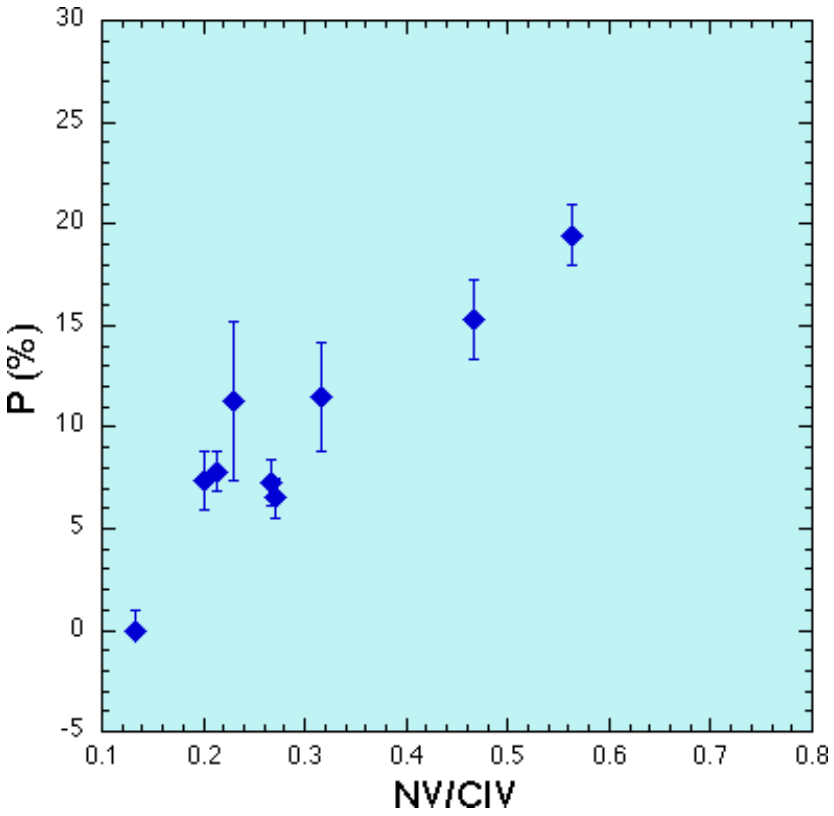
To break the α/Z degeneracy in the UV spectrum, we have to go to the optical restframe spectrum in the IR

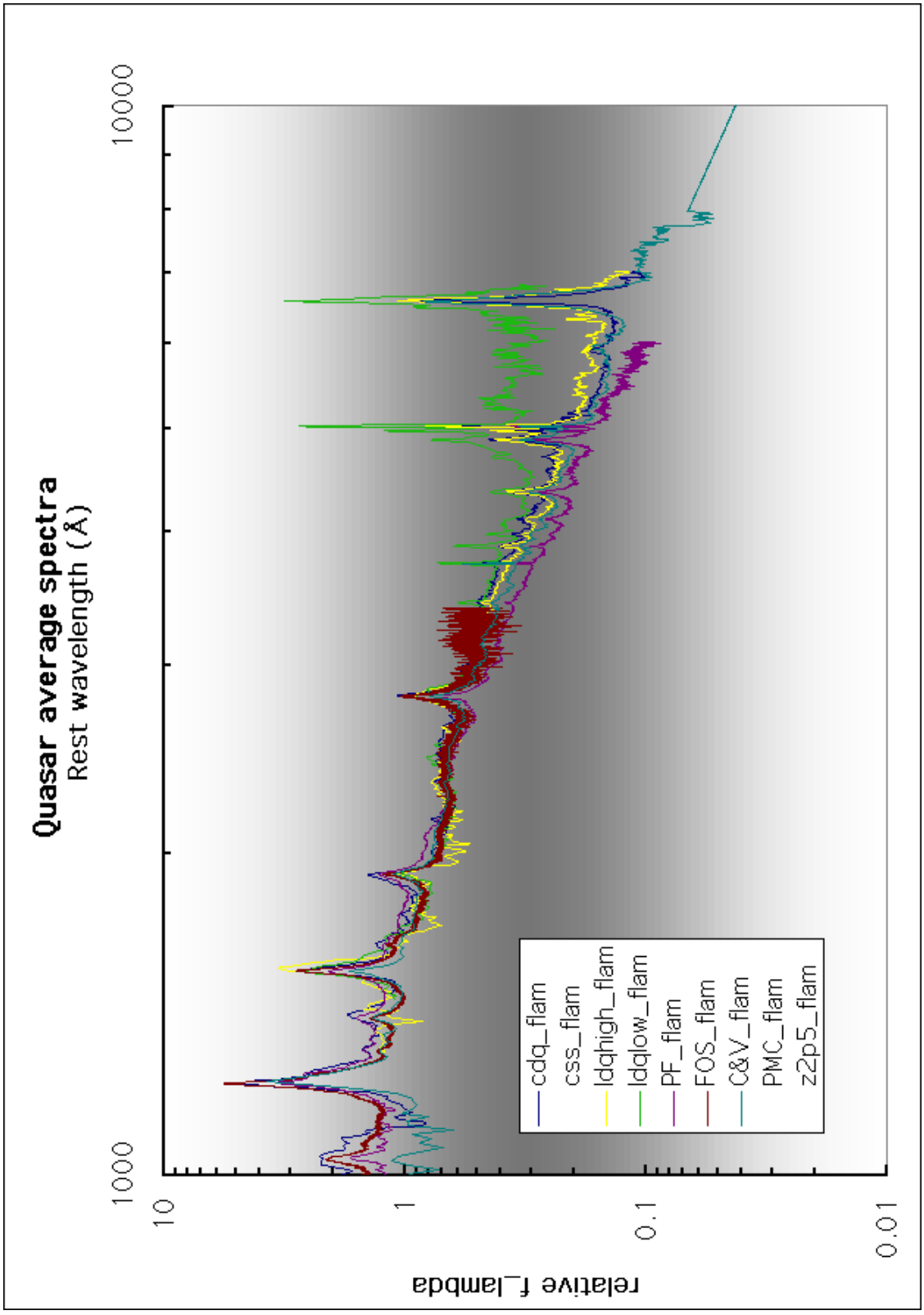
Conclusions

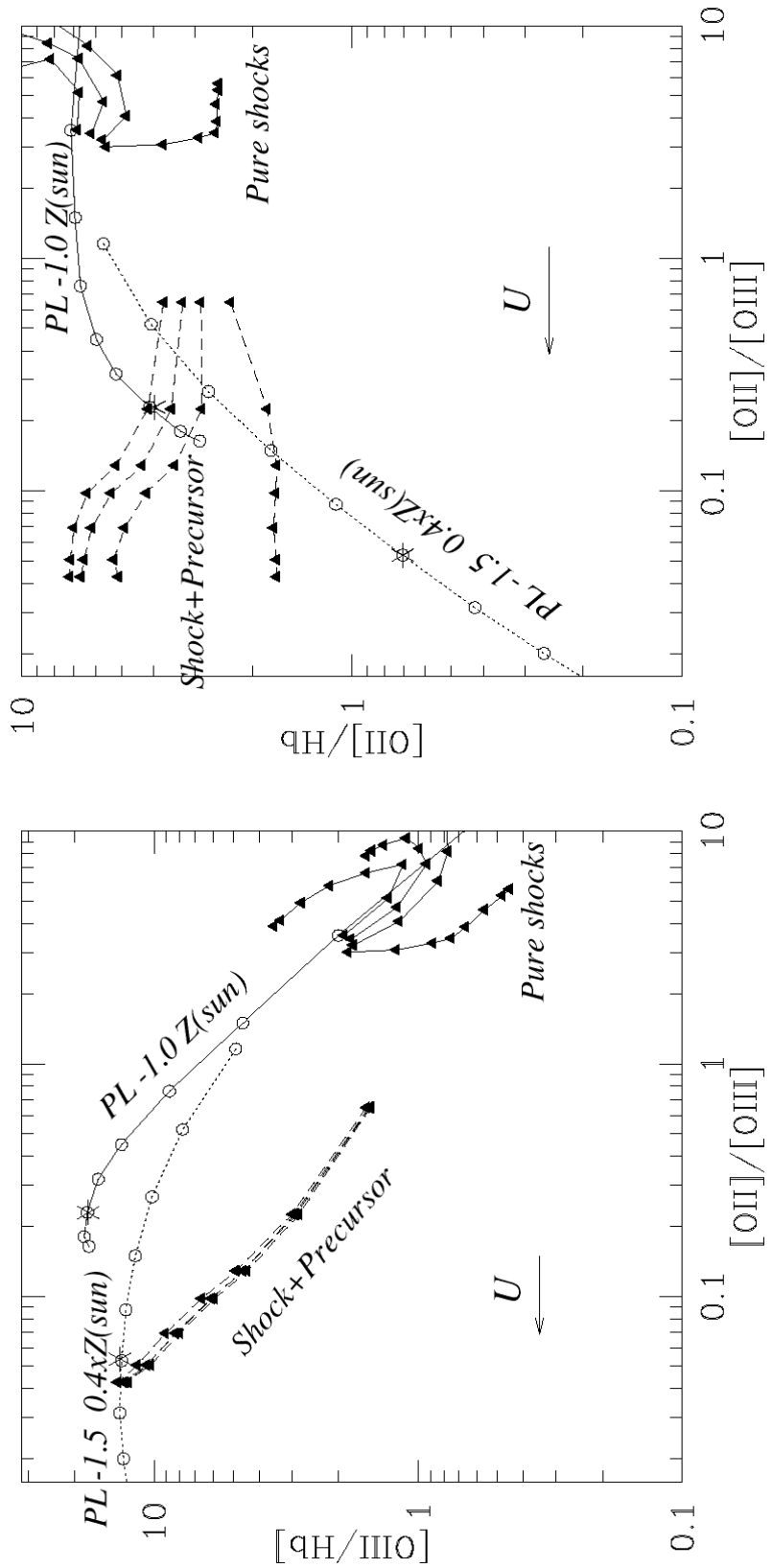
- ❏ Powerful radio galaxies contain (hidden) QSO nuclei whose EUV emission ionizes the extended gas along the radio axis and whose FUV emission we see scattered by extended dust structures
- ❏ The scattered component generally dominates the observed UV continuum. Starburst luminosities remain high enough to observe above this scattering haze for only a short time
- ❏ The powerful radio galaxies are homogeneous in ionization state but show large variations in N/C which are correlated with continuum polarization and Lyα destruction
- ❏ We are probably observing the effects, not of a gross evolution with z, but of a ‘micro-evolution’ during the chemical enrichment produced by a massive starburst. The quasar acts as a ‘flash bulb’ an illuminates the current evolutionary state of the ISM at some Δt (~ 100 Myr) after the burst

Our 9 Keck sources only






Quasar average spectra
Rest wavelength (Å)
relative f_lambda
10000
1000
10
1
0.1
0.01
cdq_flam
css_flam
ldqhigh_flam
ldqlow_flam
PF_flam
FOS_flam
C&V_flam
PMC_flam
z2p5_flam


[OII]/Hb
[OIII]/Hb
[OII]/[OIII]
PL -1.0 Z(sun)
PL -1.5 0.4xZ(sun)
Shock+Precursor
Pure shocks
U
10
1
0.1