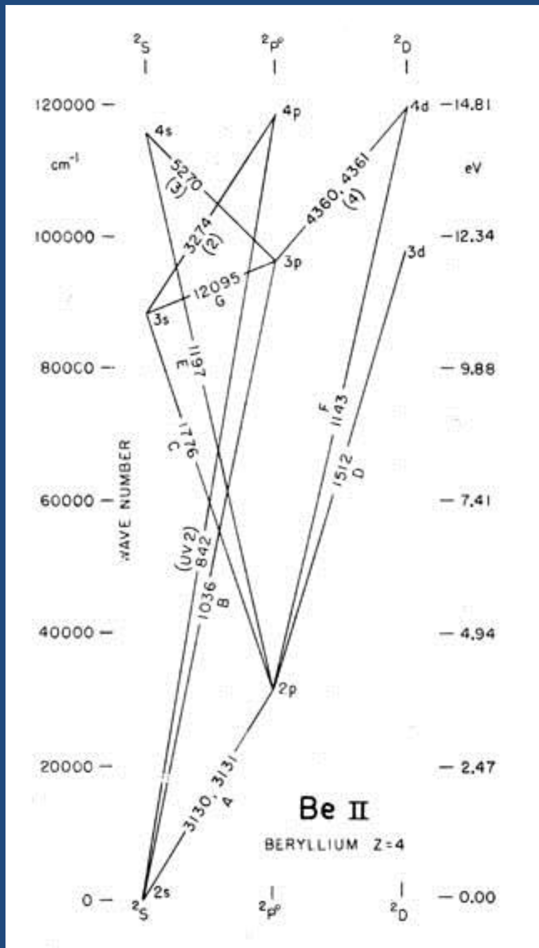
The “Nitrogen Problem” in AGN: what is strong NV 1240Å telling us?

Steve Kraemer

Catholic University of America

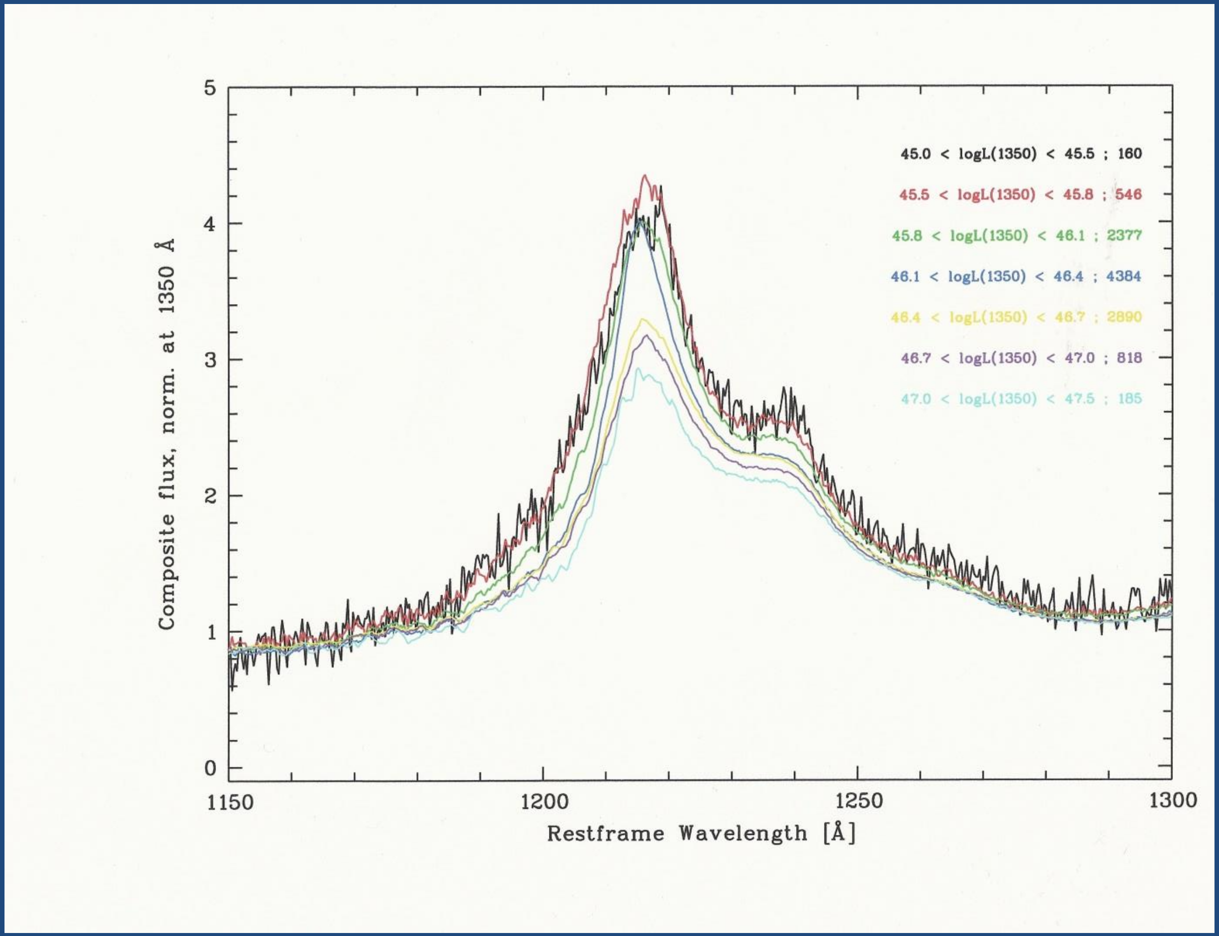
- Strong NV 1240Å , e.g., relative to CIV 1550Å and HeII 1640Å, in the spectra of QSOs has been cited as evidence for (very) super-solar abundances.
- N is a secondary element, enhanced via CNO processing in intermediate mass stars.
- High abundances suggest rapid star formation at high redshifts (see Hamann & Ferland 1999)



Grotrian Diagram for Be II – same Iso-electronic sequence

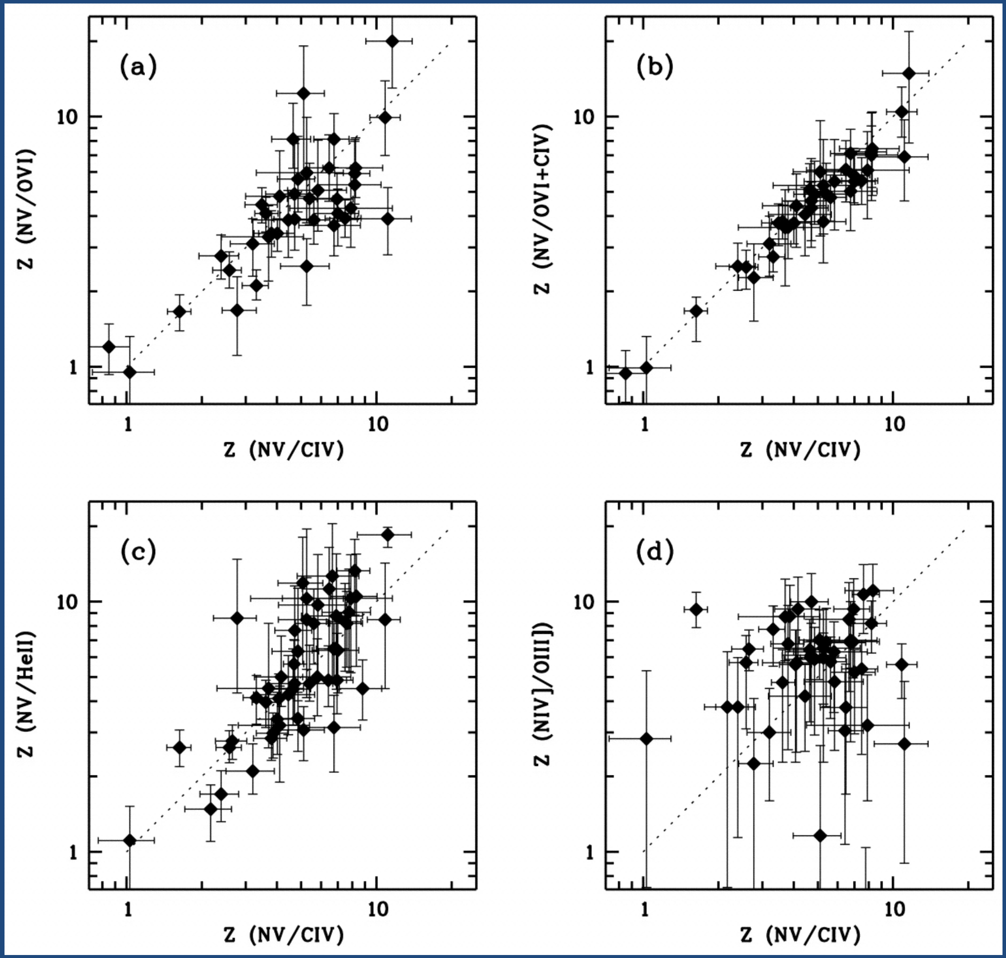
For a bit of review:

- N V is Lithium-like, IP = 77.47ev
- NV 1230.8Å, 1242.8Å, resonance doublet
- Transition: 2s ^2S - 2p $^2P^0$
- Observed in emission and absorption (always detected in intrinsic UV absorbers ; e.g. Crenshaw et al. 1999)

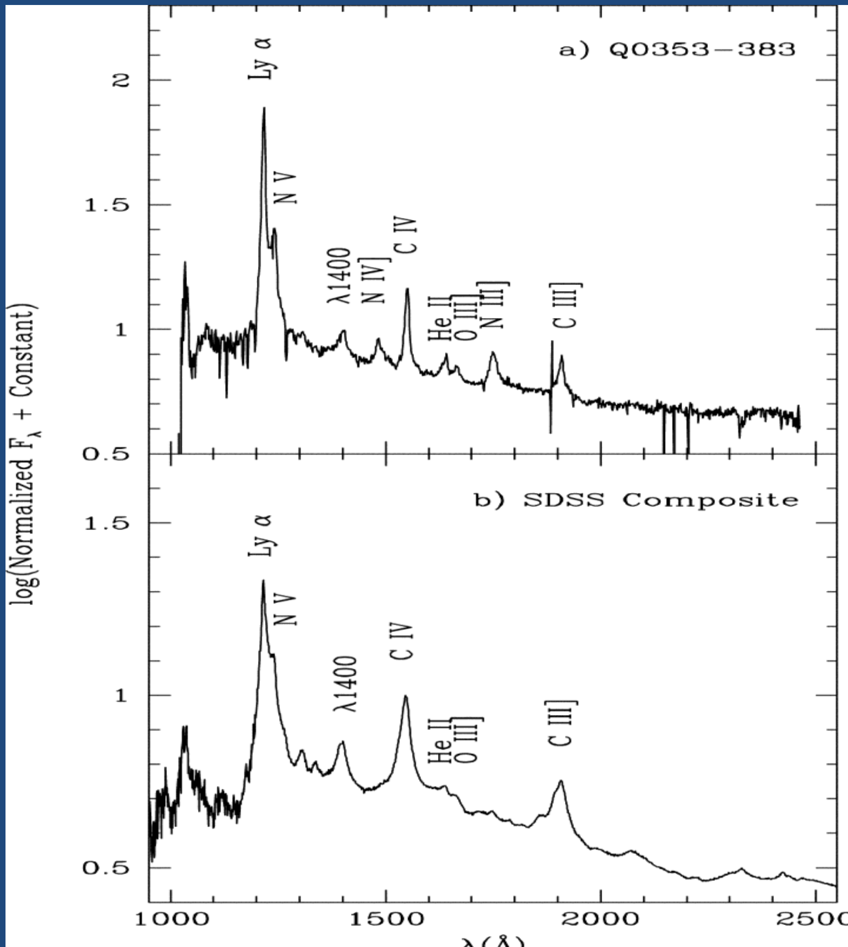


SDSS QSO composite Ly-α/NV 1240Å profiles in luminosity bins (courtesy of Stefan Frank). As L increases, the NV becomes relatively stronger. This appears mostly correlated with $\dot{M}$. Suggests relation between metallicity and accretion rate (e.g., Netzer & Trakhtenbrot 2007)

Line ratios as function of metallicity for a sample of QSOs (Dietrich et al. 2003). Metallicities were constrained via photo-ionization models.



Note that the NIV]/OIII], although indicative of Z > 1, does not require as high metallicity as the NV ratios.
Is this telling us something?



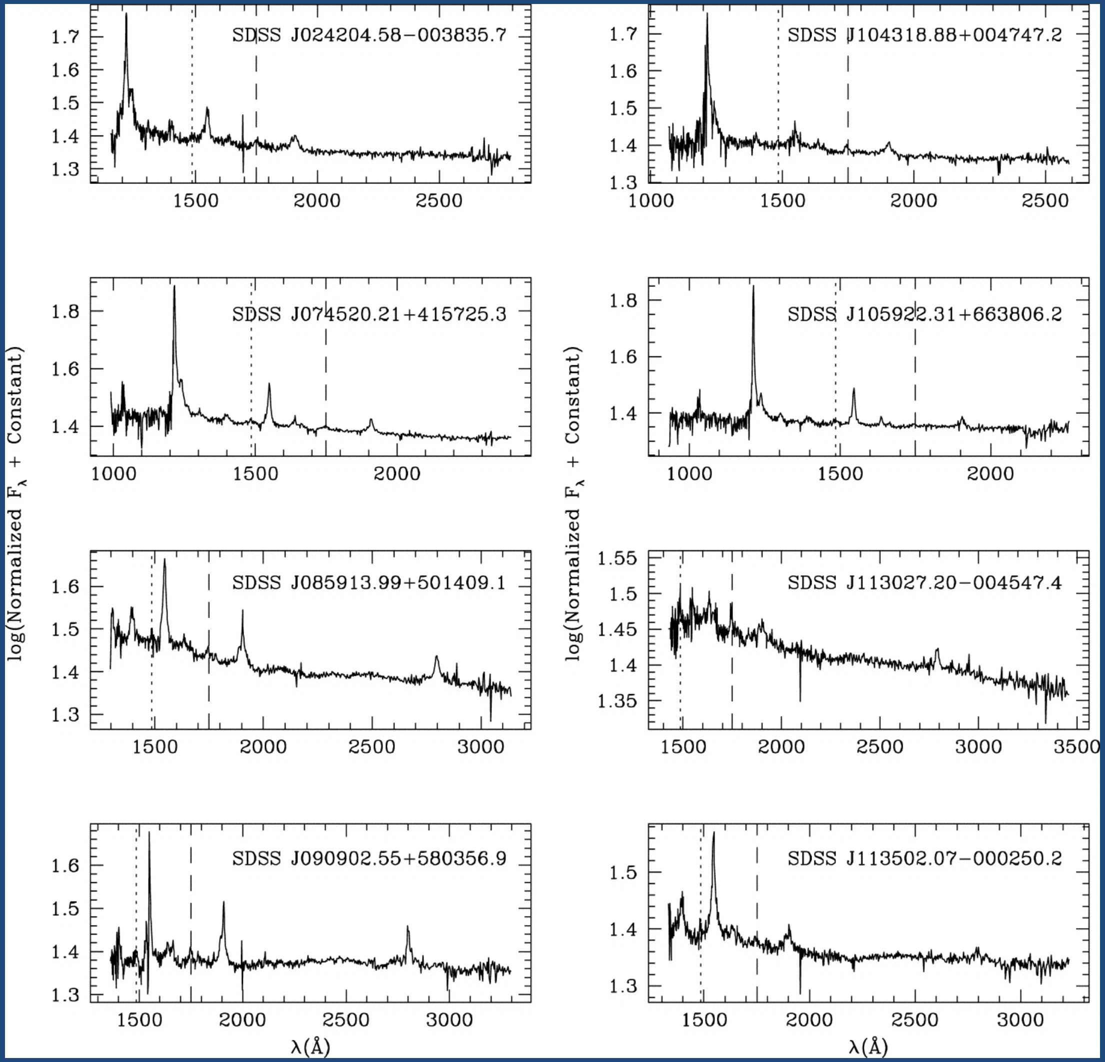
Top panel is the N-loud QSO, Q0353-383, studied by Baldwin et al. (2003).

NV 1240Å is clearly strong, as are NIV] 1486Å and NIII] 1750Å

Bottom panel shows composite QSO spectrum from the SDSS sample in Bentz et al. (2004). NV is still prominent, but other nitrogen lines are weak/undetectable.

Bentz et al. selected > 1200 SDSS QSOs. Found those with $EW_{NIV]}$ and $EW_{NIII]}$ > 2.0Å (N-rich), or one of these (N-salient).

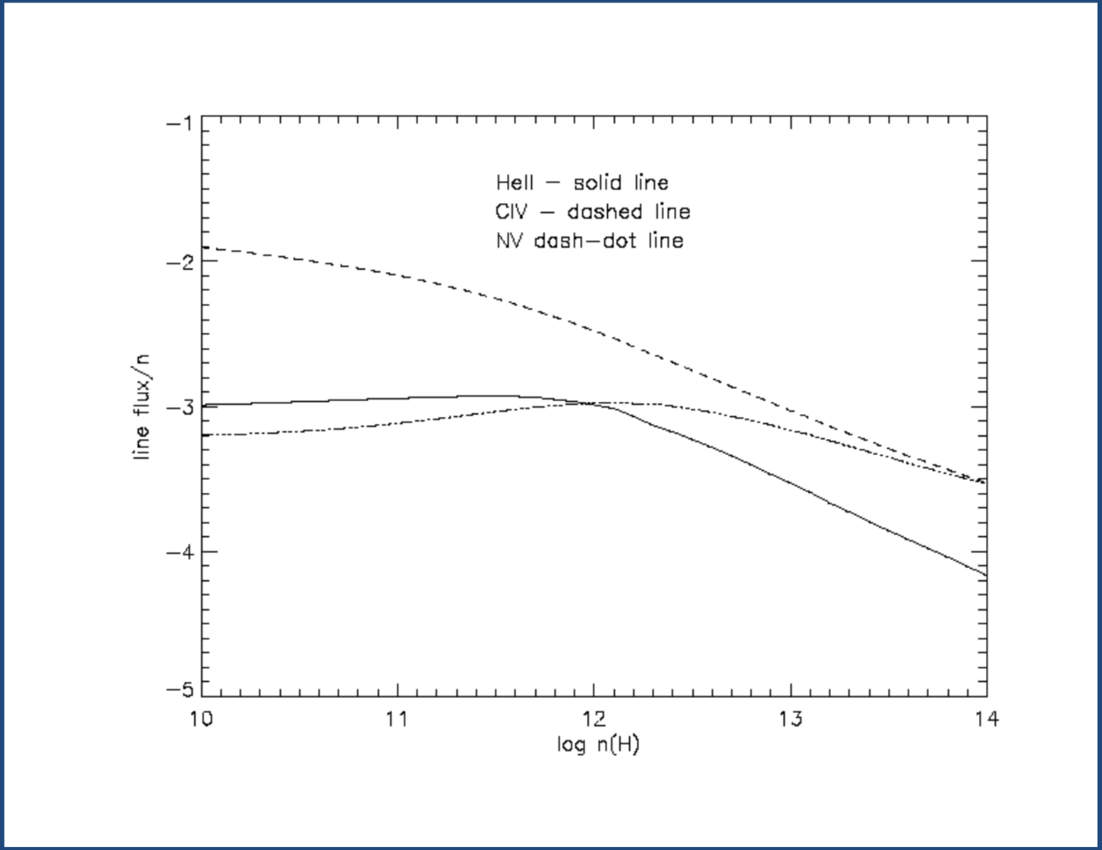
20 N-rich, 31 N-salient. Some examples shown here: dotted shows NIV], dashed shows NIII].



Seem to imply that Q0353-383 is rather unusual. But does NV strength → high abundance?

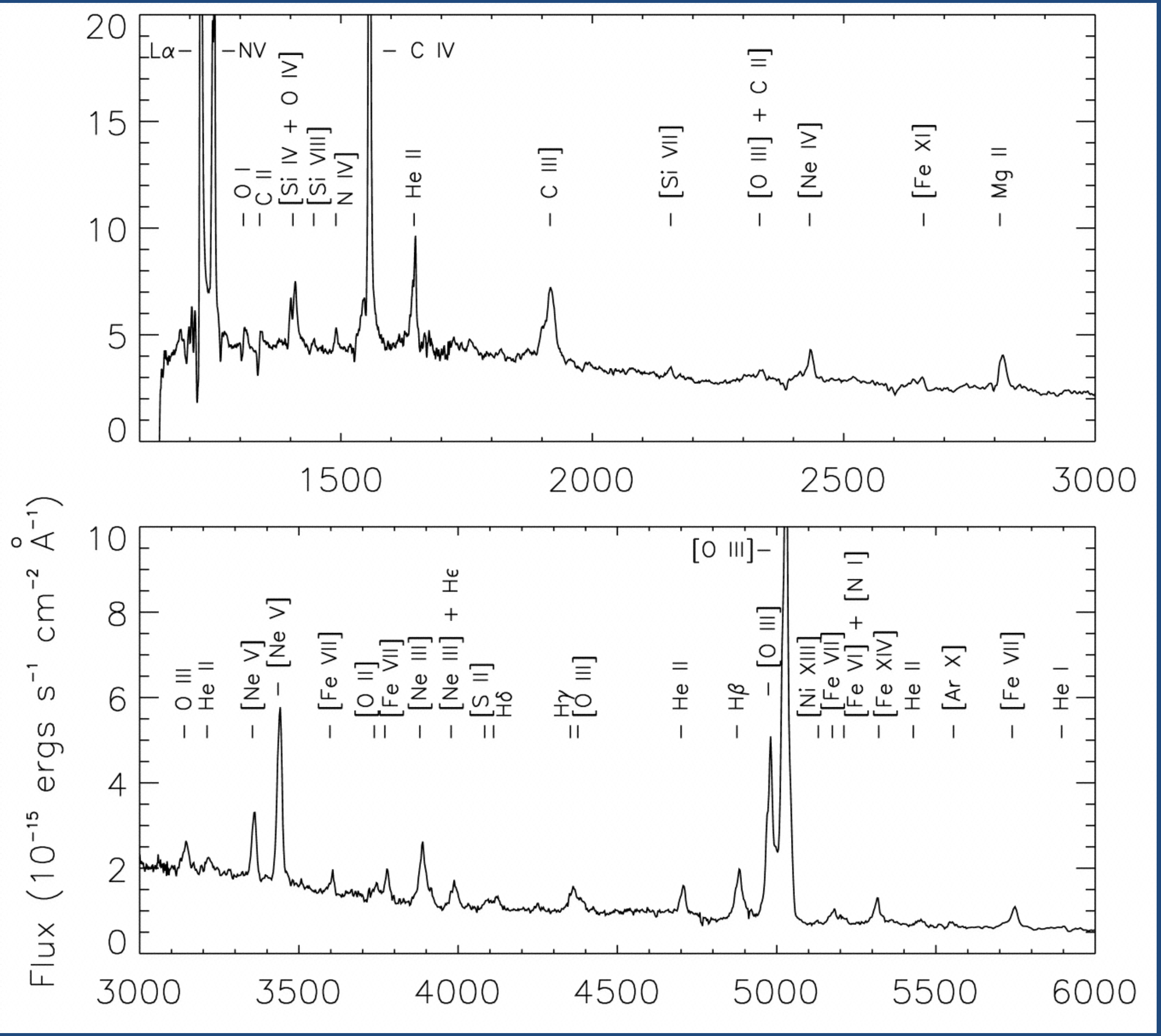
Possible that NIV] 1486Å and NIII] 1750 Å are suppressed by collisional de-excitation ($n_{crit} \sim 10^{10}$ cm^{-3}).

Along those lines, can NV 1240 be enhanced without requiring high nitrogen abundance? E.g., Radiative transfer effects? Thermalization?



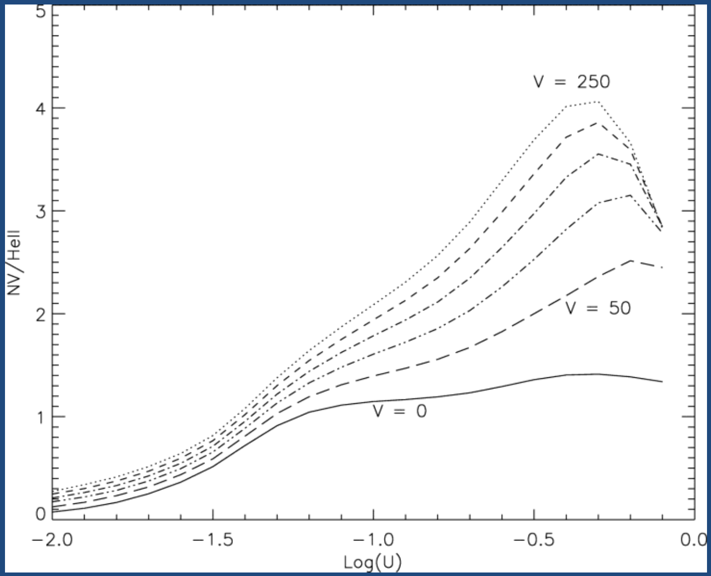
Cloudy predictions for CIV, NV and HeII strengths over range of densities (log U = -1.3, Log N_H =21), solar abundances.

However, you see enhanced NV 1240 , weak N IV] 1486 from the Narrow-Line Region. So, high density effects cannot be the answer.

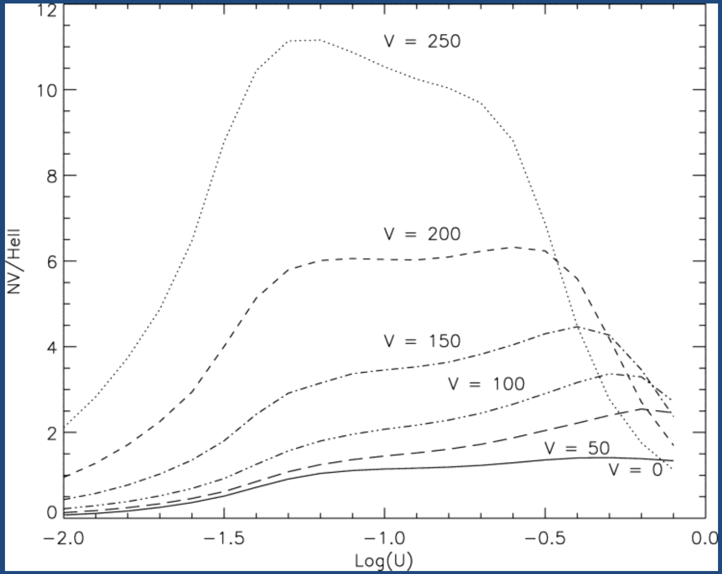


STIS combined G140L, G230L, G430L spectra of the ``Hot Spot'' in the nucleus of NGC 1068. Note NV1240/HeII > 1. Estimated density ~ 10^4 cm^{-3}

How about photo-excitation/scattering? Hamann & Korista (1996) estimated only ~18% of broad NV 1240 could be due to scattering (including contribution from Ly-α). What about NLR conditions?

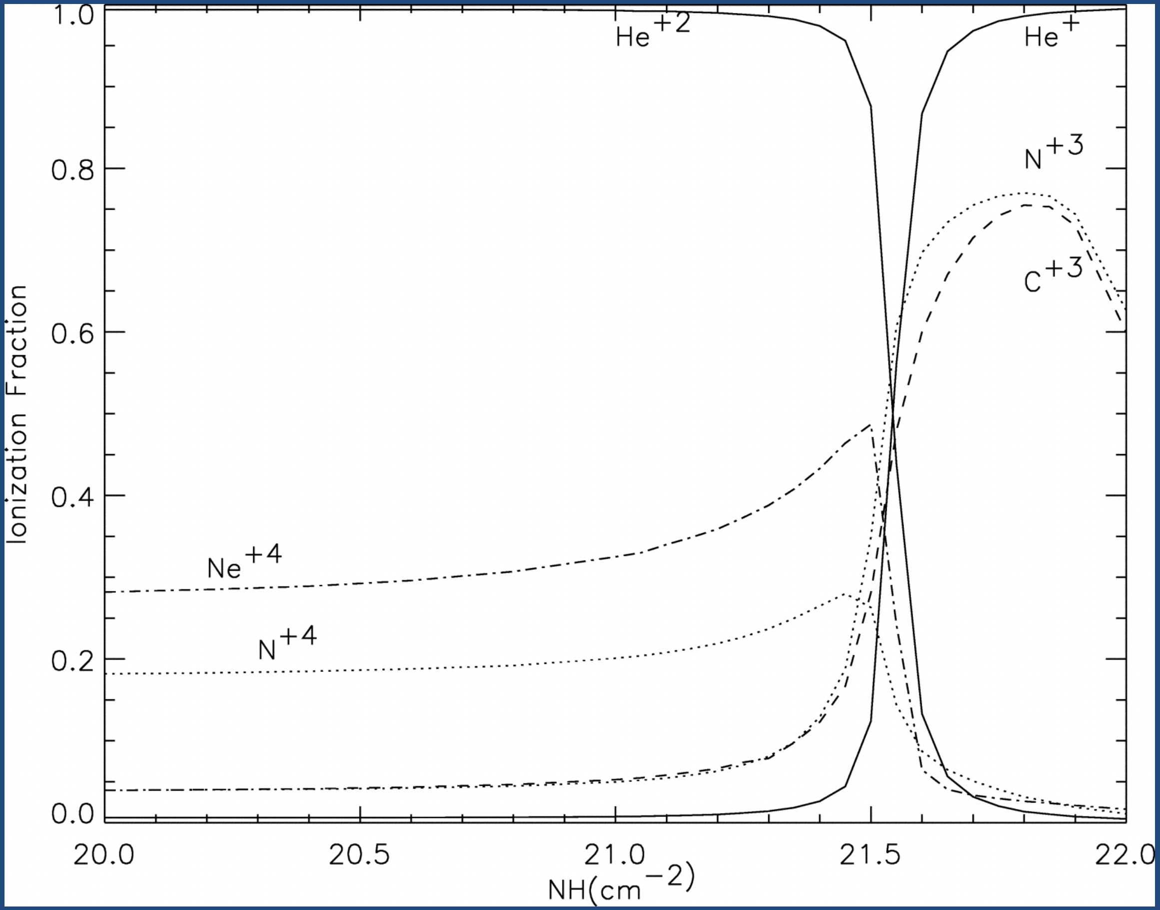


Effect of micro-turbulence on NV/HeII for NLR conditions (Kraemer, Bottorff, & Crenshaw 2007).

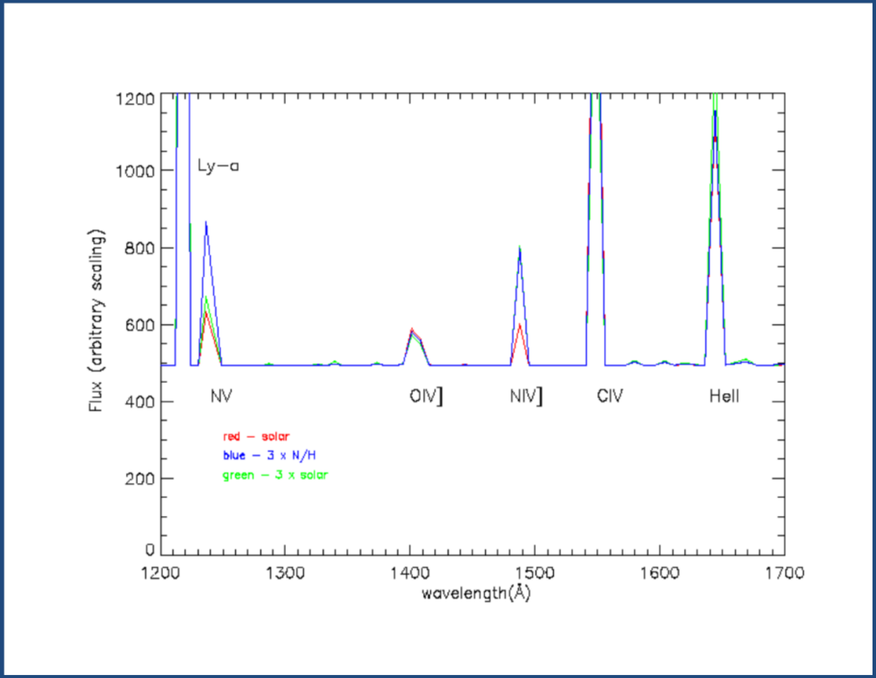


Including dissipative heating boosts NV/HeII into range of "Hot Spot". *But, also increases NIV].*

Simply put, the problem is that HeII opacity limits size of zone where NV 1240 arises

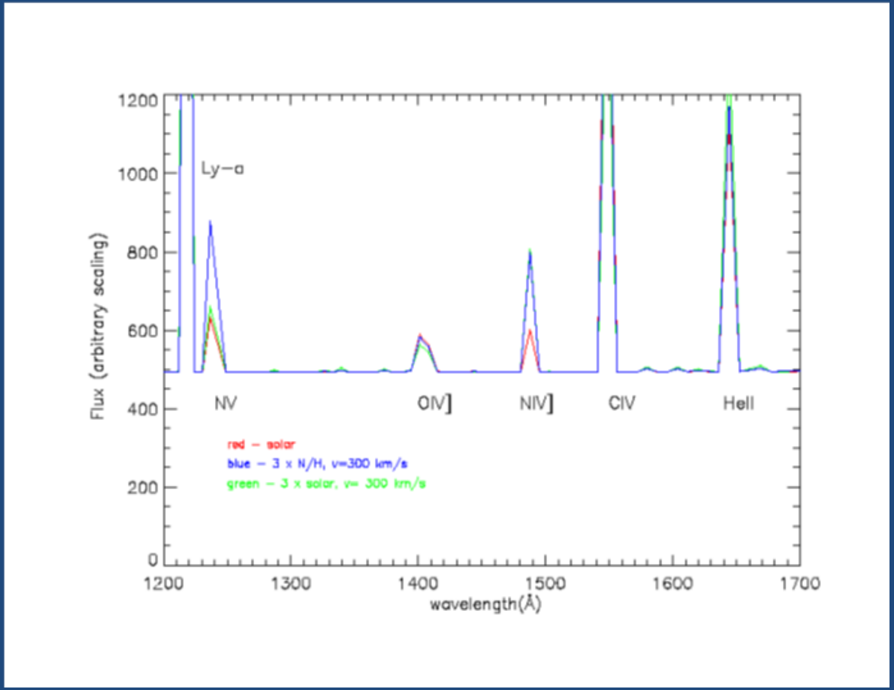


Ionization fractions for fixed ionization parameter. Note N^{+4} vanishes when gas is optically thick at HeII Lyman limit.



Output spectra from Cloudy models (log U = -1.3, log N_H = 21, log n_H =4) showing effects of increase abundances.

Models with same parameters demonstrating effects of micro-turbulence.



Higher N/H, stronger NV 1240
and **NIV] 1486**

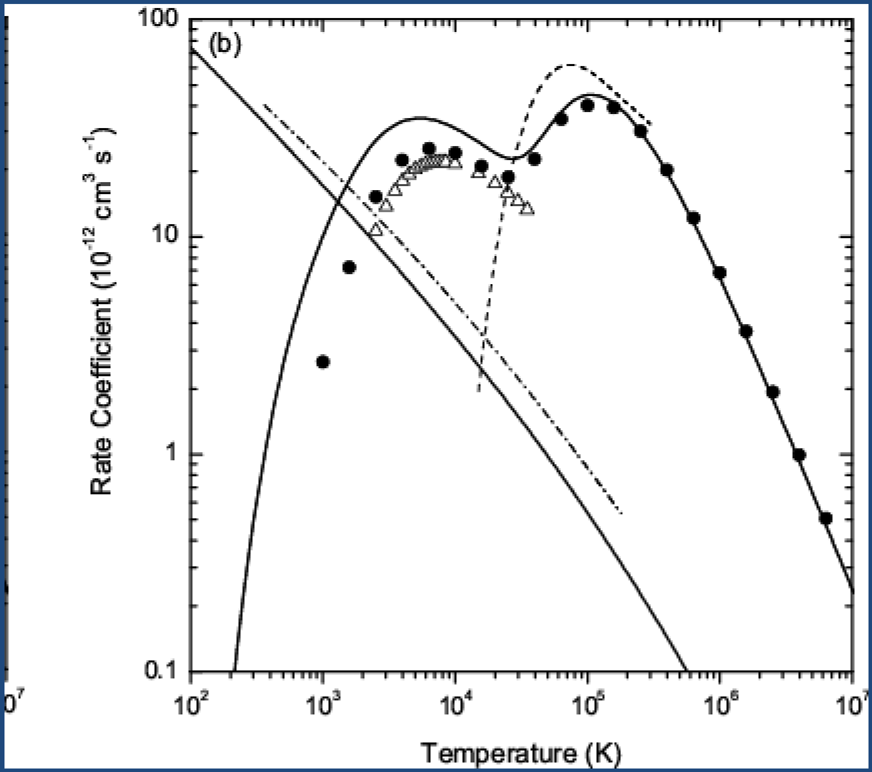
To recap:

- NV 1240 is very strong in AGN, perhaps related to $\dot{M}$
- Scattering/Photo-excitation doesn't work
- Dissipative heating *could,* but has unwanted effects (e.g. more NIV])
- High Abundances could explain NV strength, but not NIV] and NIII] weakness.

NOTE: this does not suggest solar N/H. NLR photo-ionization studies (e.g. optical/UV, Groves et al. 2004; X-ray, Turner et al. 2003, Kraemer et al. 2014) indicate N/H is in range of 2 – 3 times solar.

But, how do we get more NV and less NIV], NIII]? Is this an ionization/recombination effect?

How about dielectronic (and trielectronic) recombination?

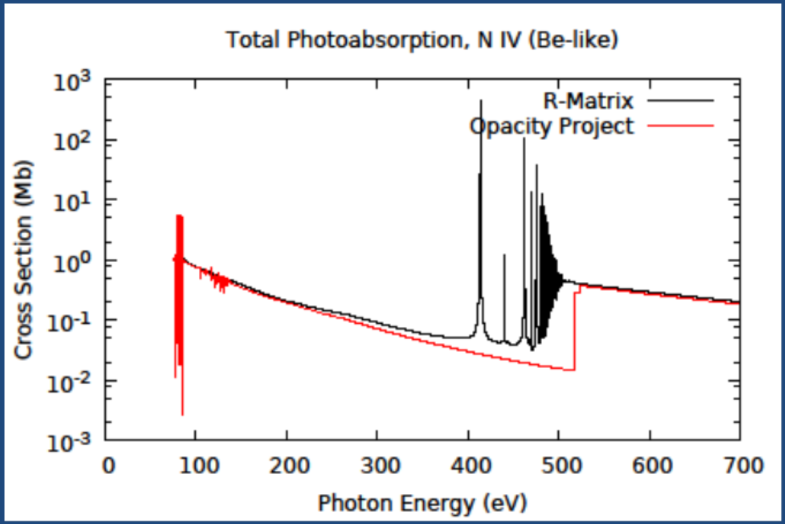


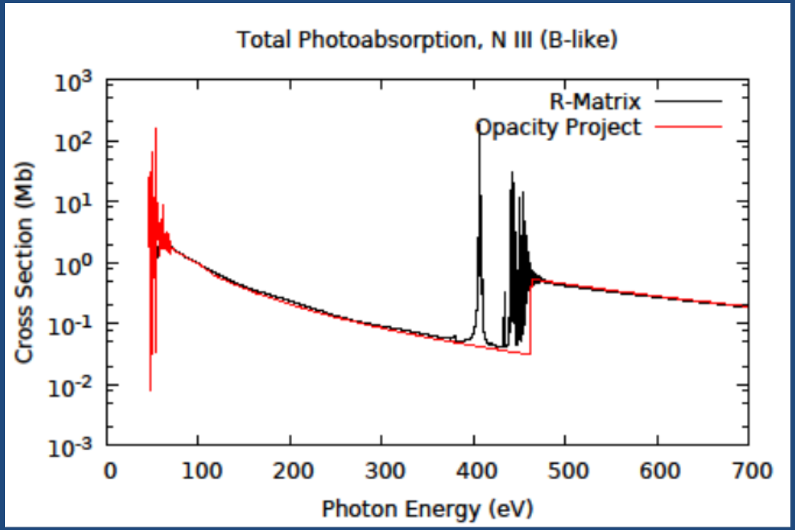
Storage ring measurements of recombination rates for N^{+3} (Fogle, Badnell et al. 2005). The new DR rates shown by solid line. Previous calculated rates from Badnell (solid dots), Nussbaumer & Storey (triangles), Aldrovandi & Pequignot (dashed line).

These new rates are in Cloudy and XSTAR. They would drive NIV -> NIII, which would Increase NIII] 1750. No low-Temp DR for NVI (closed shell).

Yet another suggestion: **Inner Shell Ionization**

Calculations by Garcia et al. (2009), using the Breit-Pauli R-matrix method, show strong resonances not present in previous calculations.



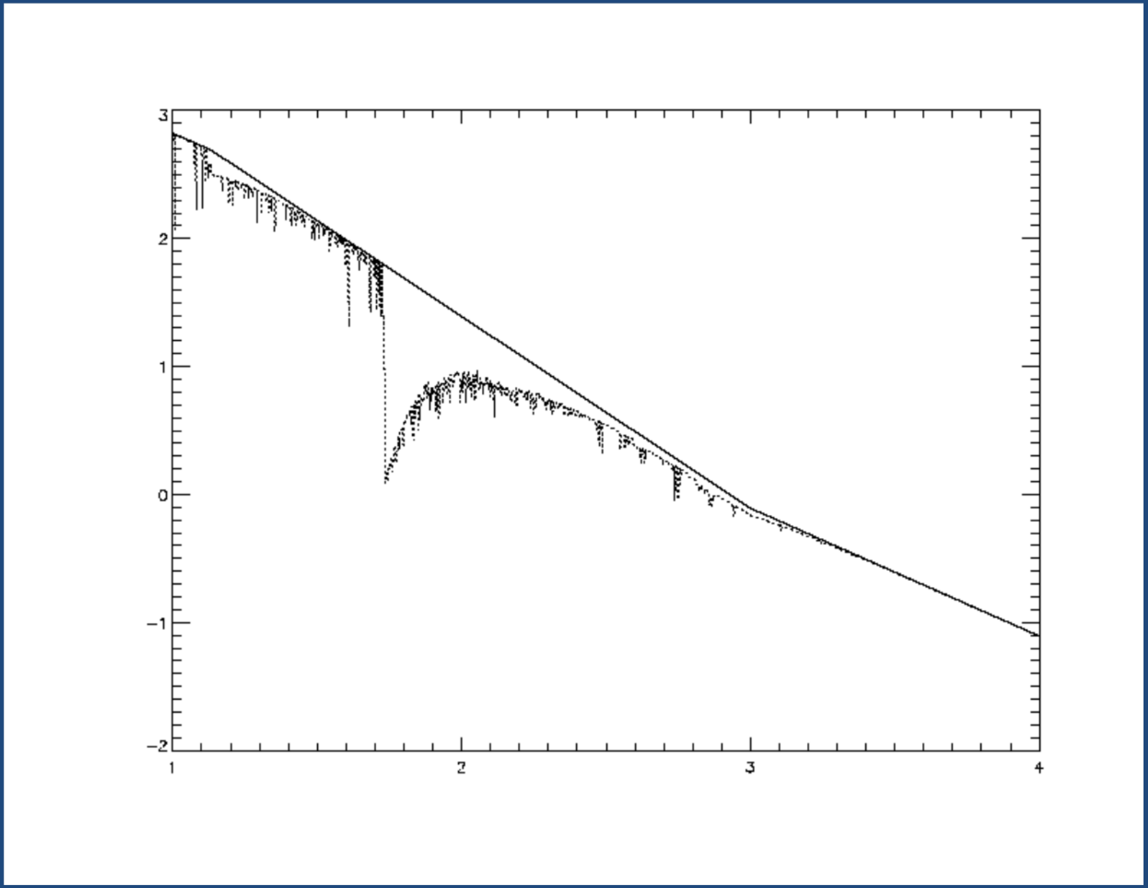


Inner shell ionization creates a vacancy in an inner shell.
Can be filled by 1) fluorescence or 2) non-radiative (Auger) transition

Afterward, resulting ion could have "jumped" several ionization states.

Photo-ionization rates from valence shell must still dominate, so how can the inner-shell ionization have an effect?

- Extension of N^{+4} zone past point where gas optically thick at HeII Lyman limit.



Incident and transmitted continua from test models shown earlier. Note gas is optically thick at 54.4 eV, but significant flux at 400 eV.

Conclusions

Unfortunately, XSTAR models don't show significant change in ionization balance with new cross-sections. Still looking into this. However:

- NV 1240Å requires some means of enhancement
- If no other nitrogen lines are strong, models will not fit the spectrum if N/H increased to fit NV.
- Some physics may be missing. What? Not sure.
- One possibility – fluorescence after inner shell ionization.