中国科学院云南天文台
YUNNAN OBSERVATORIES,CHINESE ACADEMY OF SCIENCES

# Prevalence of HeI* Absorption Line Multiplets in LoBAL Quasars

**Wen-Juan Liu**
**wjliu@ynao.ac.cn**

**Collaborators:**
**Hongyan Zhou (PRIC), Tuo Ji (PRIC), Weimin Yuan (NAOC), Tinggui Wang (USTC) et al.**

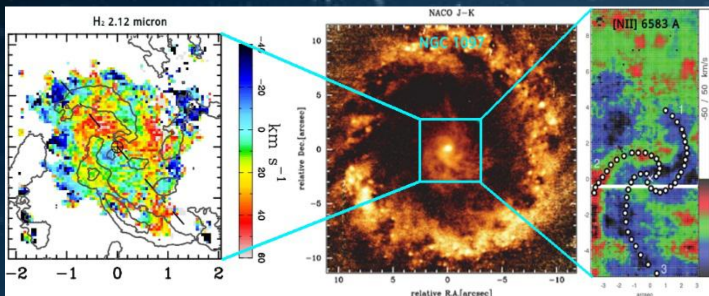
**Lijiang RM Workshop (Oct. 2016)**

# Fueling

# The interplay between AGNs and galaixes

# Feedback

NGC 1097 inflow



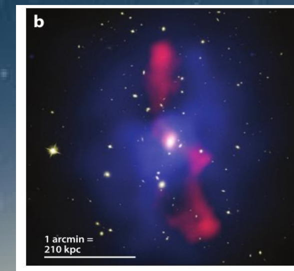

Davies et al. (2009), Prieto et al. (2005), Fathi et al. (2006)

jet

1Mpc

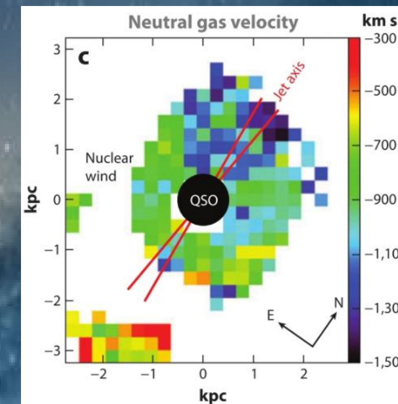
100kpc

10kpc




Fabian (2012)

Mrk 231




Rupke et al. (2002)

star formation

BLR

ultra-fast outflows

molecular outflows

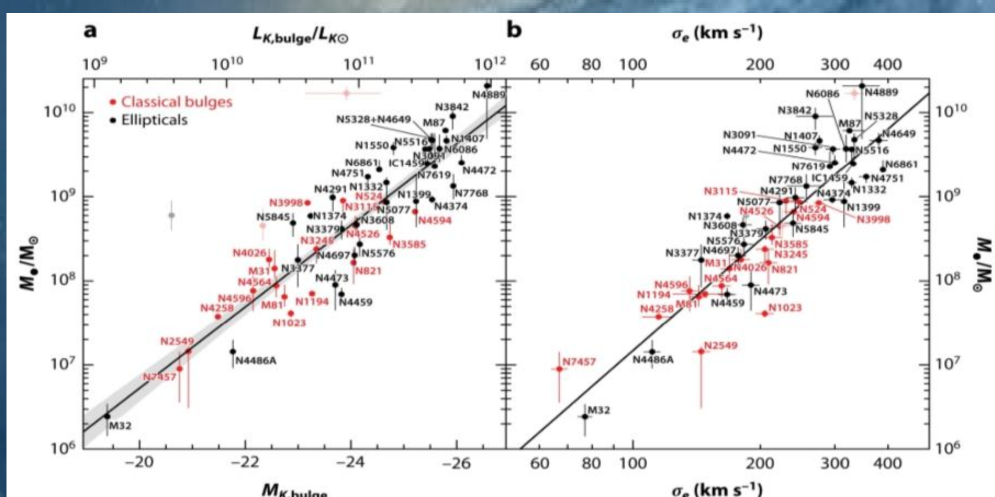
1kpc 100pc 10pc 1pc 0.1pc 0.01pc 0.1pc 1pc 10pc 100pc 1kpc 10kpc

molecular gas

hot dust

SMBH

ionised outflows

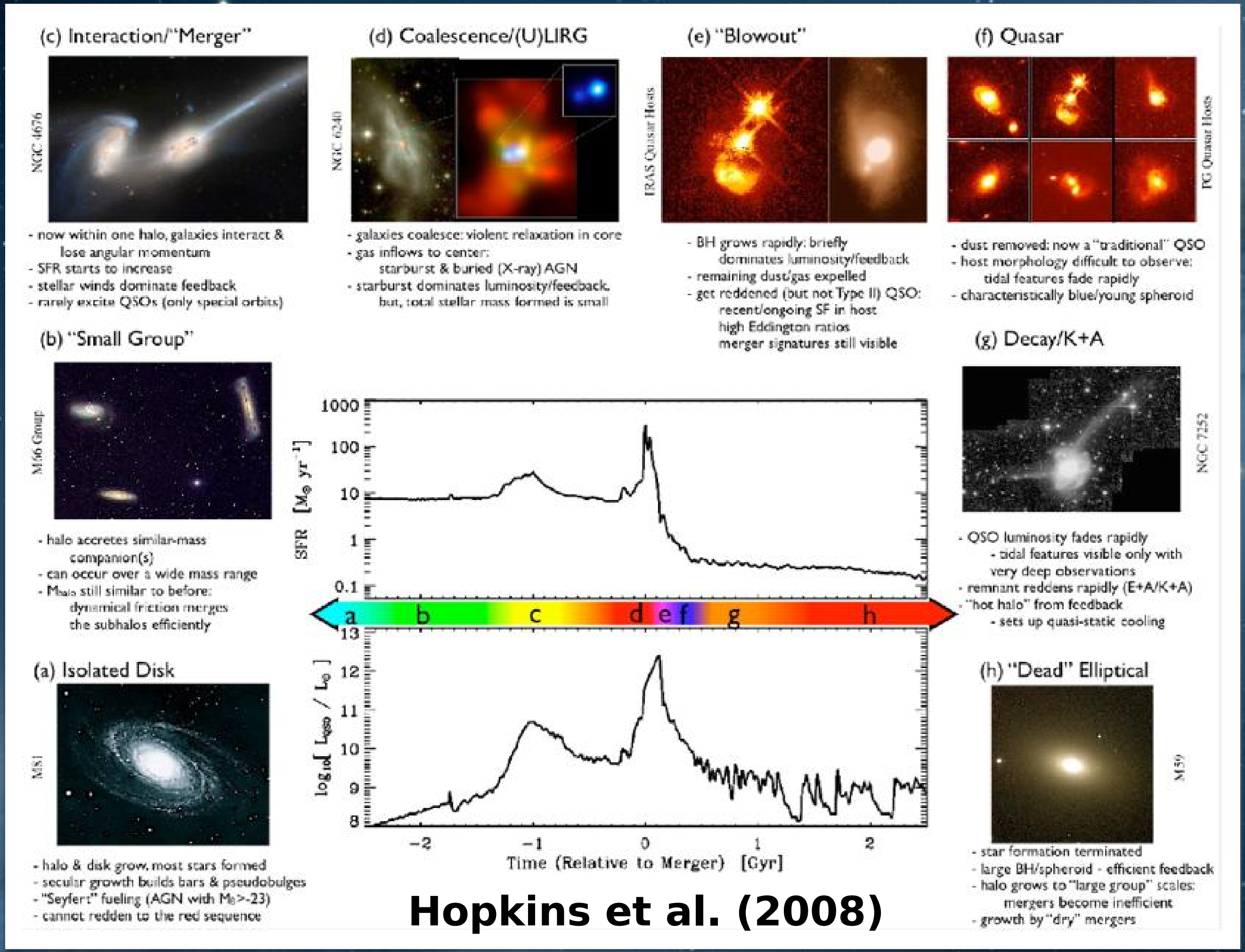



Kormendy & Ho (2013)

$M_{BH}—\sigma_\star$

$M_{BH}—M_{bulge}$

# A popular working model




**Hopkins et al. (2008)**

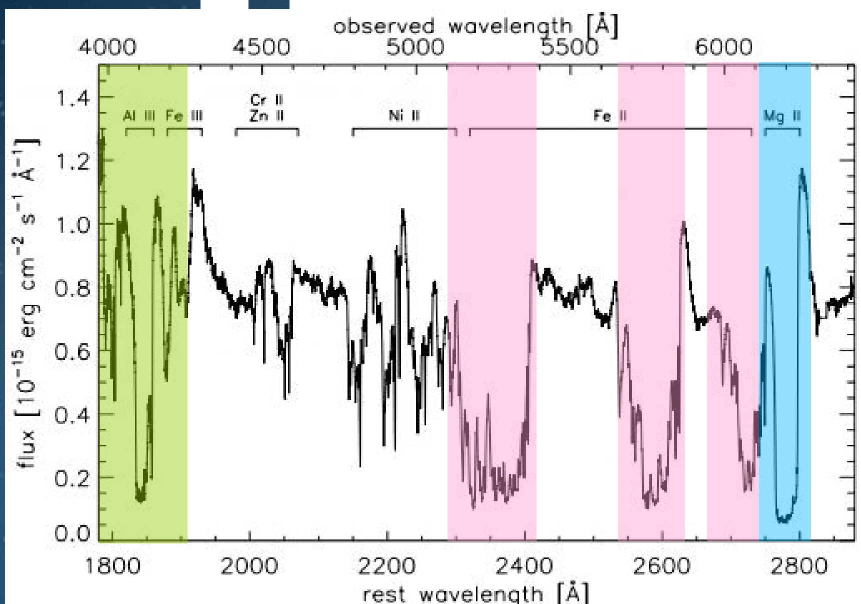
- How do major mergers drive gas on large scales into the nuclear region and trigger AGN activities?
- How do AGN outflows affect the host galaxies in detail?
- What is the effect of AGN outflows on star formation? Positive or negative?  Both?

# Broad absorption line (BAL) quasars

15-30% quasars all observed to have BAL features

Common BALs: OVI, NV, CIV, Si IV, AlIII, FeIII, MgII, FeII

Difficulties in studying BALs using common absorption lines:
--- Easily **saturated** or **blended**




**de Kool et al. (2002)**

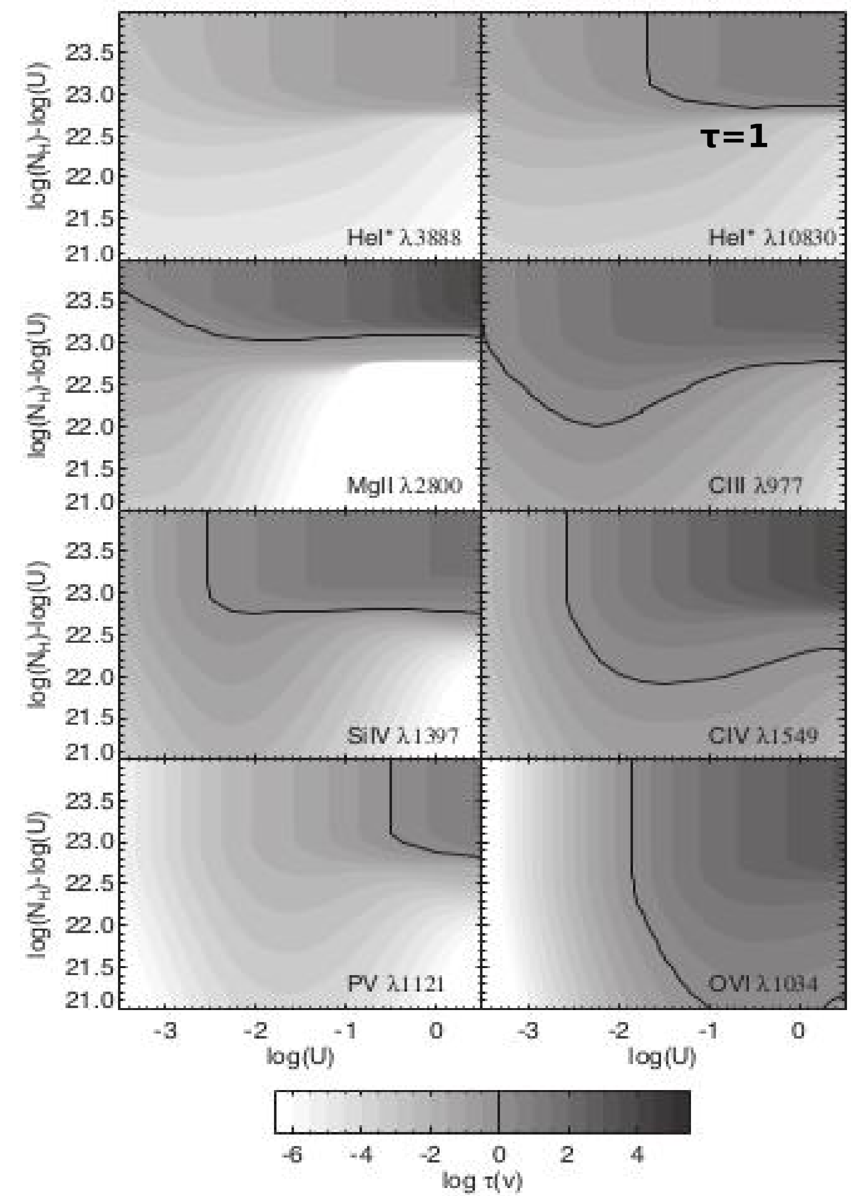
Table 10

Properties of Measured Outflows to Date

| Object | $R^a$ (kpc) | $\log N_H$ ($cm^{-2}$) | $\log U_H$ | $\log \dot{E}_k$ ($erg\ s^{-1}$) | $\dot{M}$ ($M_\odot\ yr^{-1}$) |
|---|---|---|---|---|---|
| QSO 0059−2735 | 0.001–0.05 | $\gtrsim 21.5^c$ | −0.7 | $\gtrsim$41.1–42.8 | $\gtrsim$0.2 |
| 3C 191 | 28 | 20.3 | −2.8 | 44.0 | 310 |
| QSO 1044+3656 | 0.1–2.1 | 20.0–22.0 | −1.0 to −6.0 | 44.5–45.4 | 74–530 |
| FIRST 1214+2803 | 0.001–0.03 | 21.4–22.2 | −2.0 to −0.7 | 41.6–43.8 | 0.3–55 |
| FIRST 0840+3633 | 0.001 | ~21.3 | <−1.8 | >41.9 | >0.3 |
| FIRST 0840+3633[d] | 0.23 | … | … | … | … |
| QSO 2359−1241 | 3 | 20.6 | −2.4 | 43.7 | 93 |
| SDSS J0838+2955 | 3.3 | 20.8 | −1.9 | 45.7 | 590 |
| SDSS J0318−0600 | 6 or 17 | 19.9 or 20.0 | −3.1 or −2.7 | 44.8 or 45.4 | 120 or 450 |

**Dunn et al. (2010)**

# HeI* BALs -- an approach to extensively and quantitatively study AGN outflows




**Leighly et al.** (2011)

**1. HeI* λλ10830, 3889, 3189...**

easy to observe from the ground,
well separated, no blending problems.

**2. Large oscillator strengths difference:**

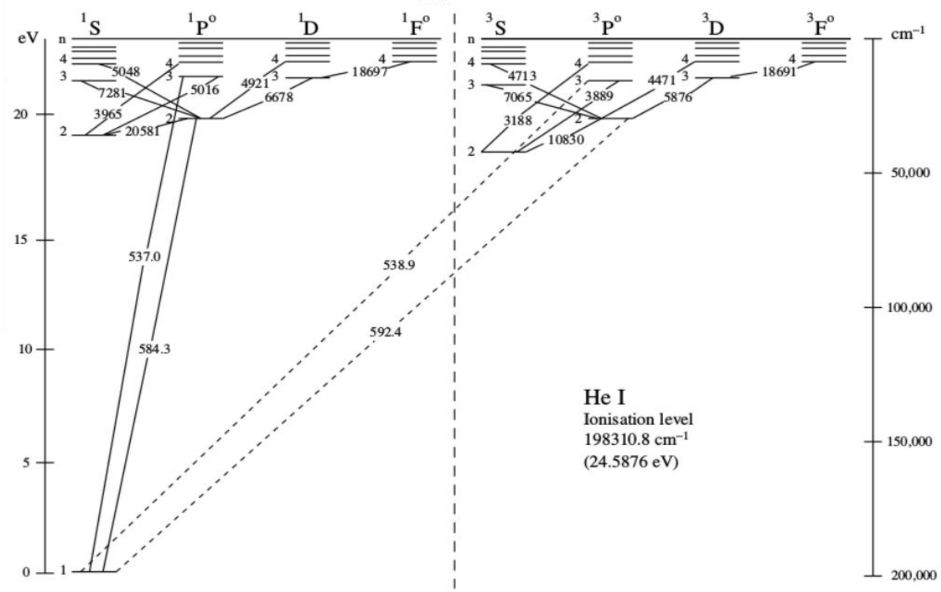
fλ (HeI* 10830:3889:3189) ---
23.5: 1: 0.33

**3. Low abundance -- hard to saturate**

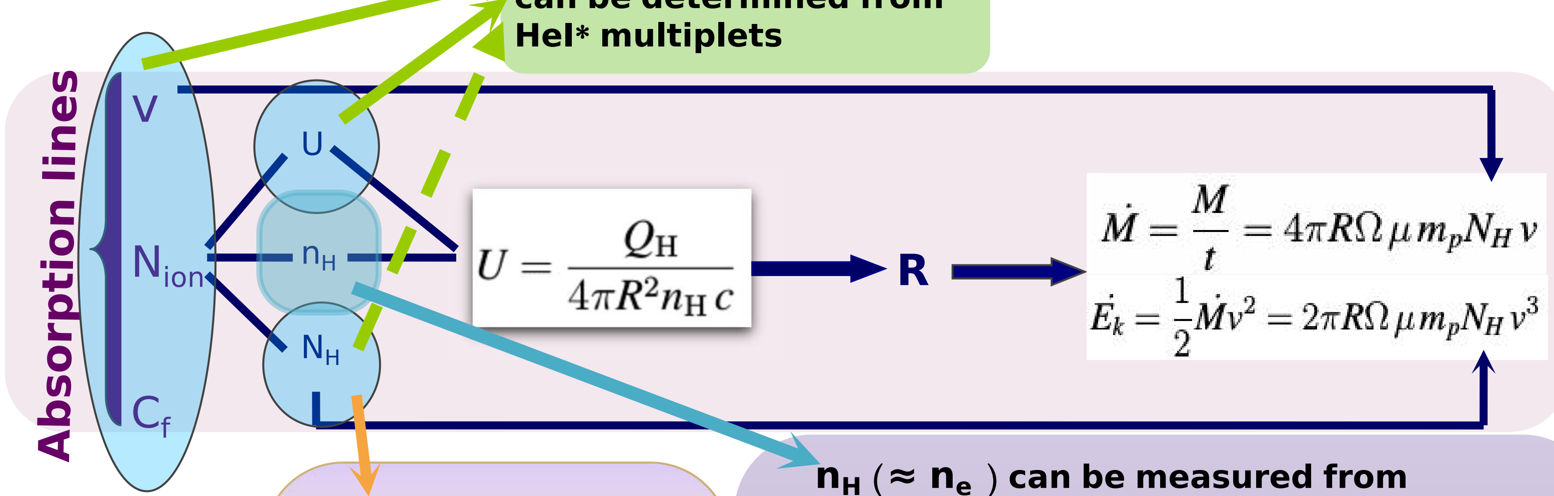
$$\frac{N(2^3S)}{N_{He^+}} = \frac{5.79\times10^{-6}T_4^{-1.19}}{1+3110T_4^{-0.51}n_e^{-1}}$$

Clegg 1987

$$T\sim 10000\ \mathrm{K},\ N_{2^3S}/N_{He^+}\sim 5.8\times10^{-6}$$

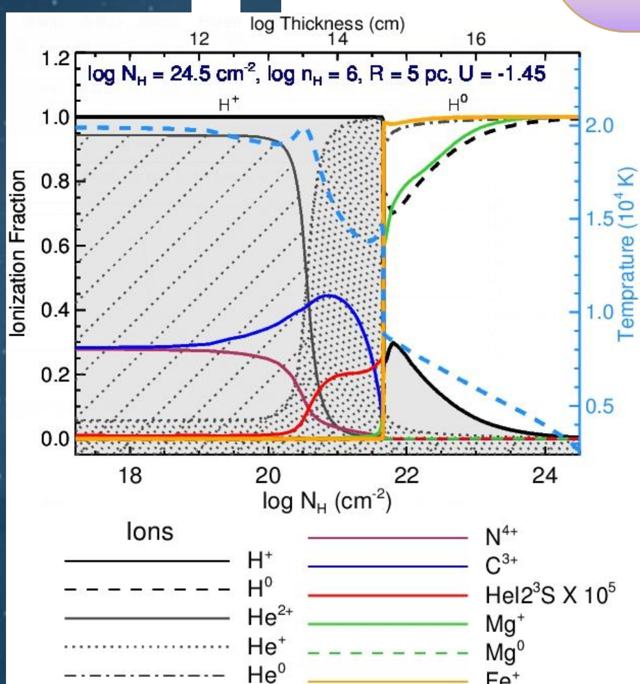


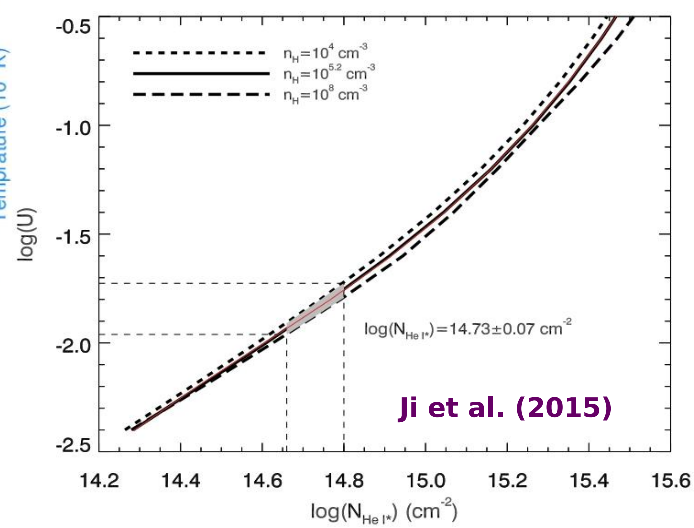
**Physcial parameters that can be determined from HeI* multiplets**




**Even the non-detection of HeI* abs. can set a upper limit for $N_H$**

**$n_H$ ($\approx n_e$ ) can be measured from**
**(1) density—sensitive absorption lines of excited FeII, SiII, CII states**
**(2) recombination time scale, $t_{rec} \sim 1/n_e$**
**(3) density—sensitive lines, such as Balmer abs. to determine upper limit to $n_e$**



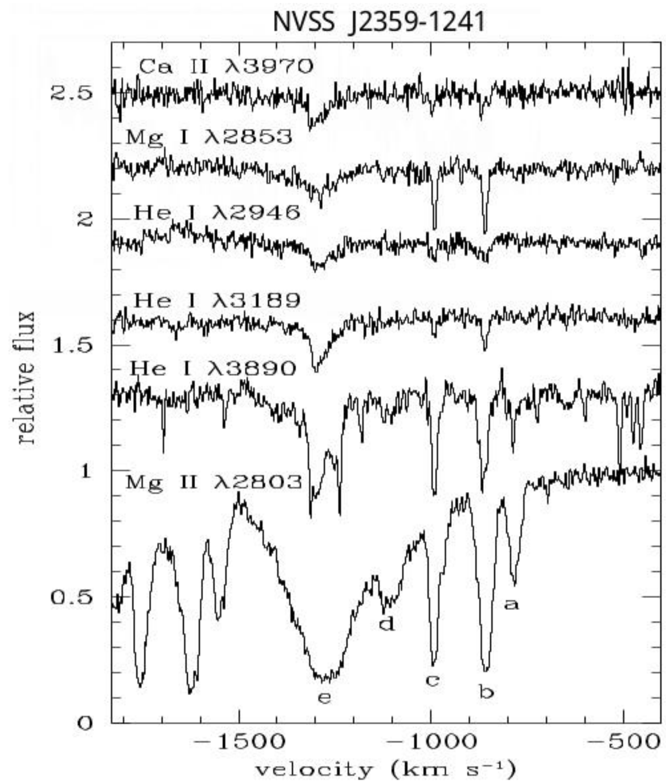




**HeI* multiplets serve as important diagnostics for physical conditions of AGN outflows**

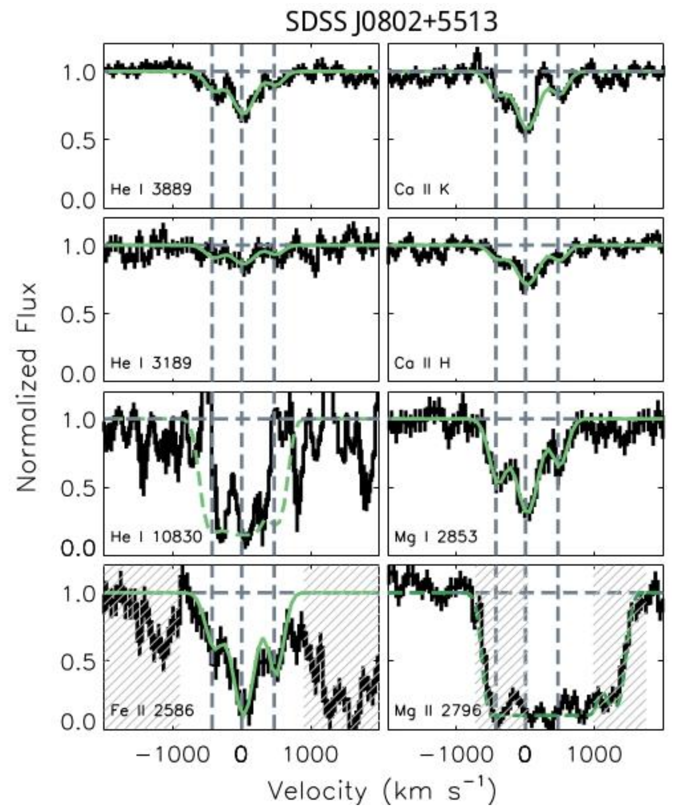
# The HeI*λ3889 BAL sample

- Before this work, only 11 HeI* BAL quasars had been reported, e.g., Mrk 231, FBQS J1115+3822, ...

- Most of the 11 show both MgII and HeI* λ3889 absorption lines with the same blueshift.

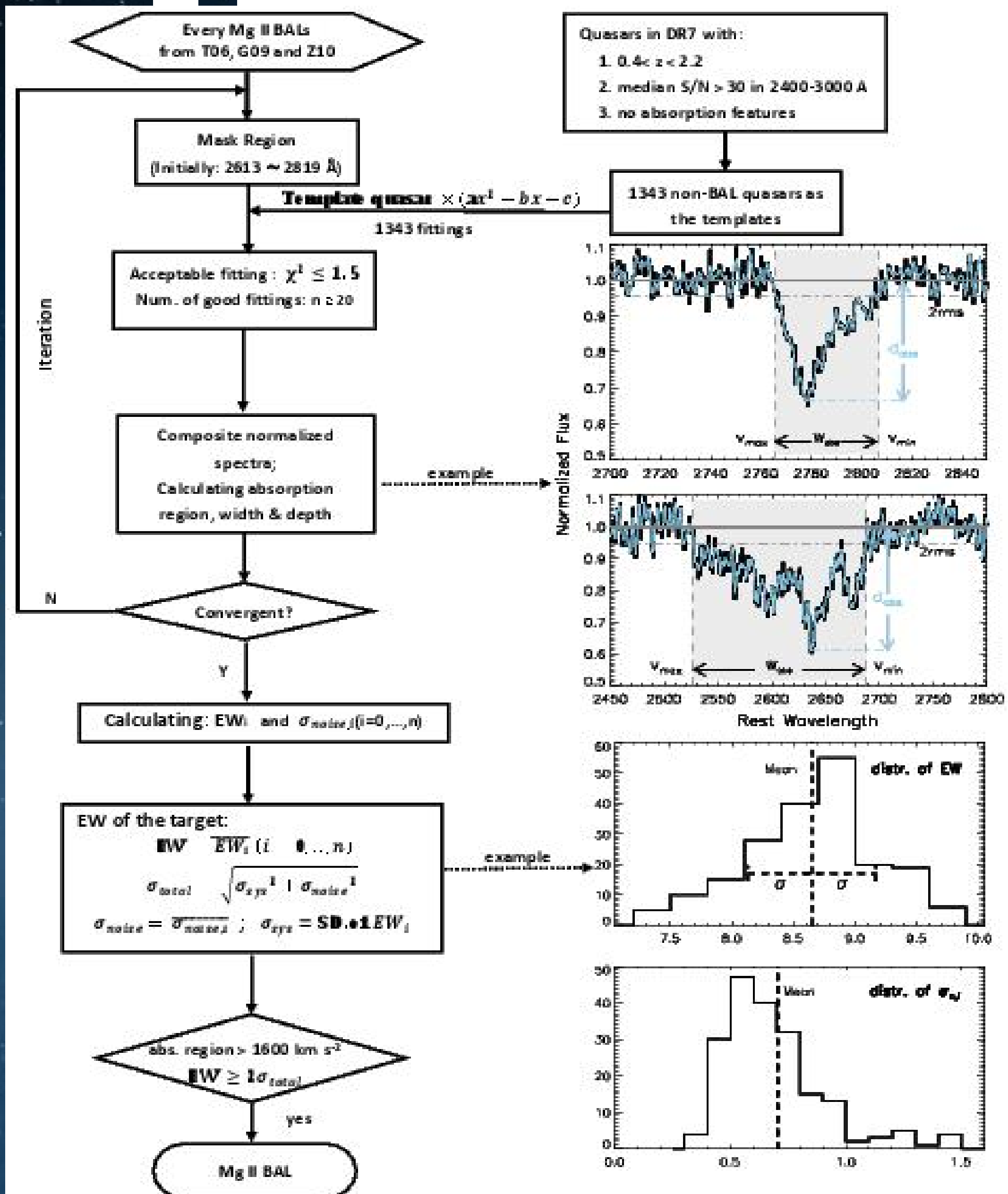



Arav et al. (2001)

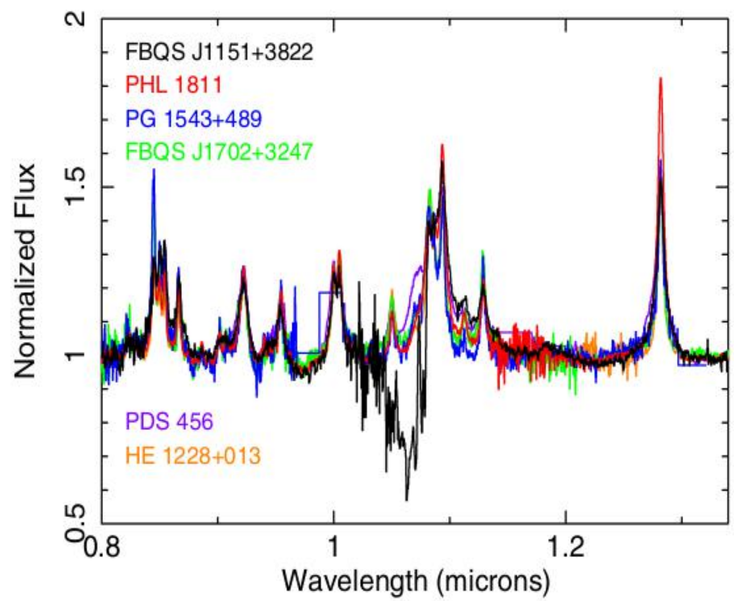



Ji et al. (2015)

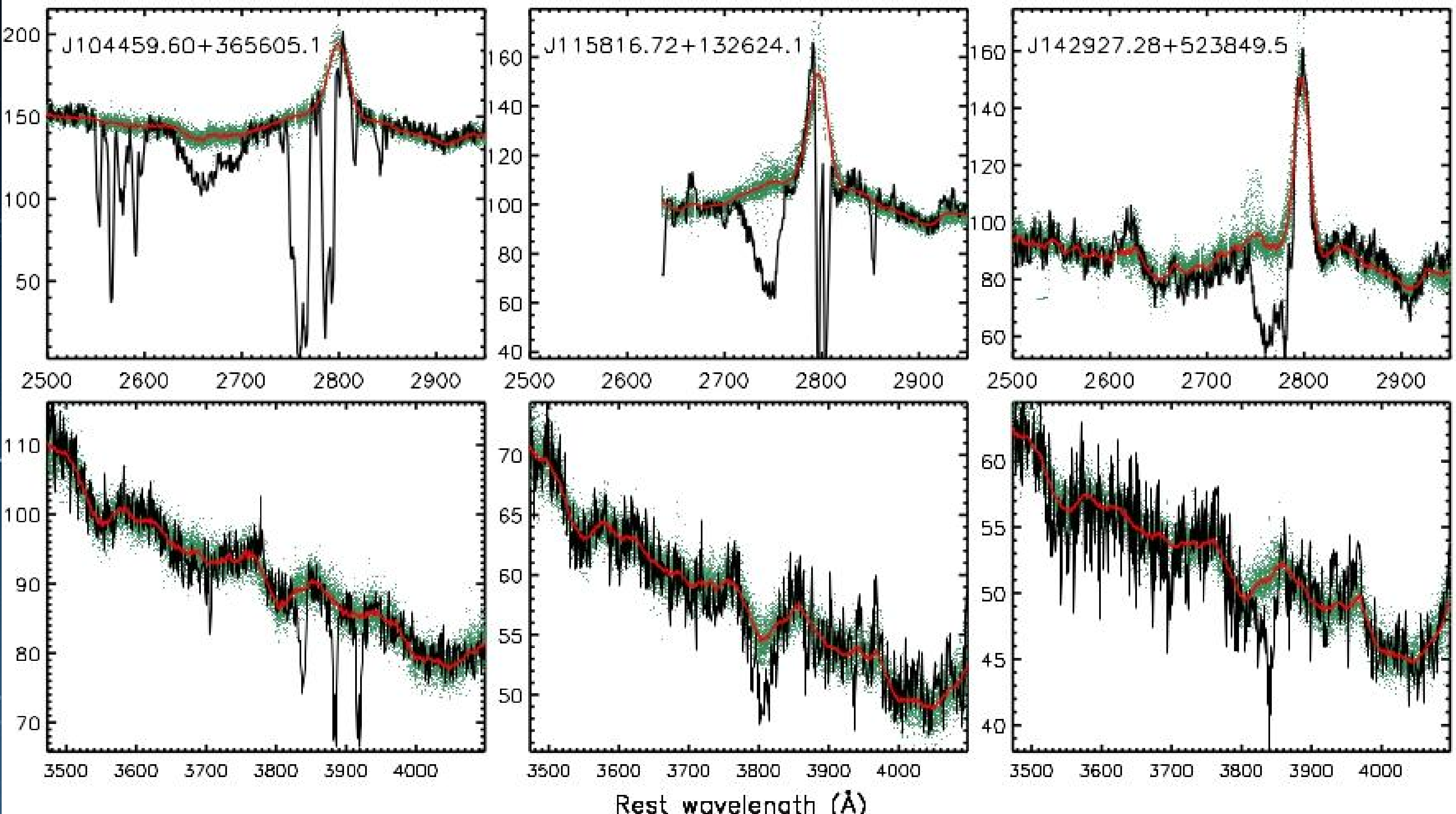
# The "pair-matching" method




**Based on the similarity of continua and emission line profiles between BAL and non-BAL quasars, except for the possible dust reddening effect.**

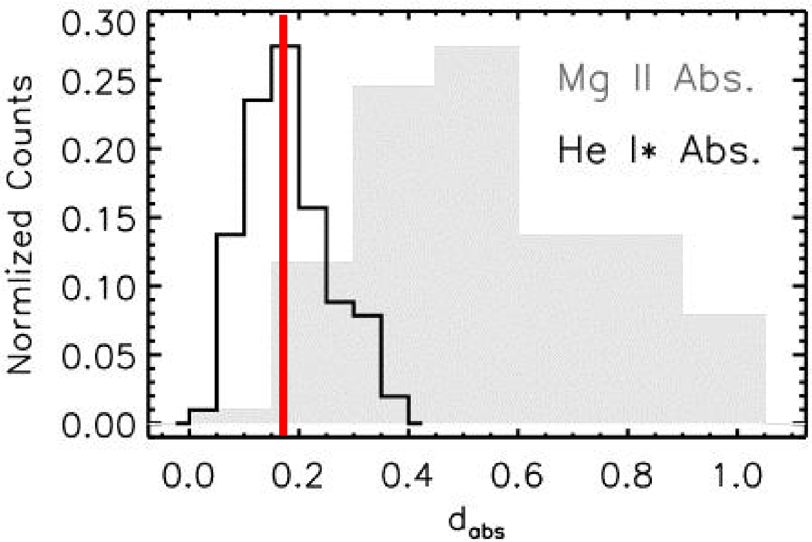


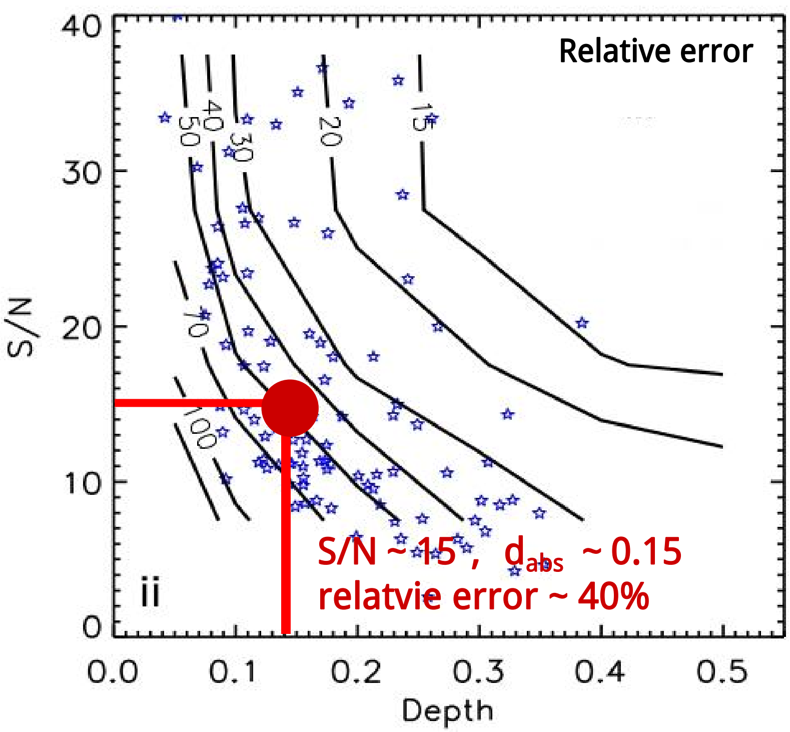

**Leighly et al. 2011**

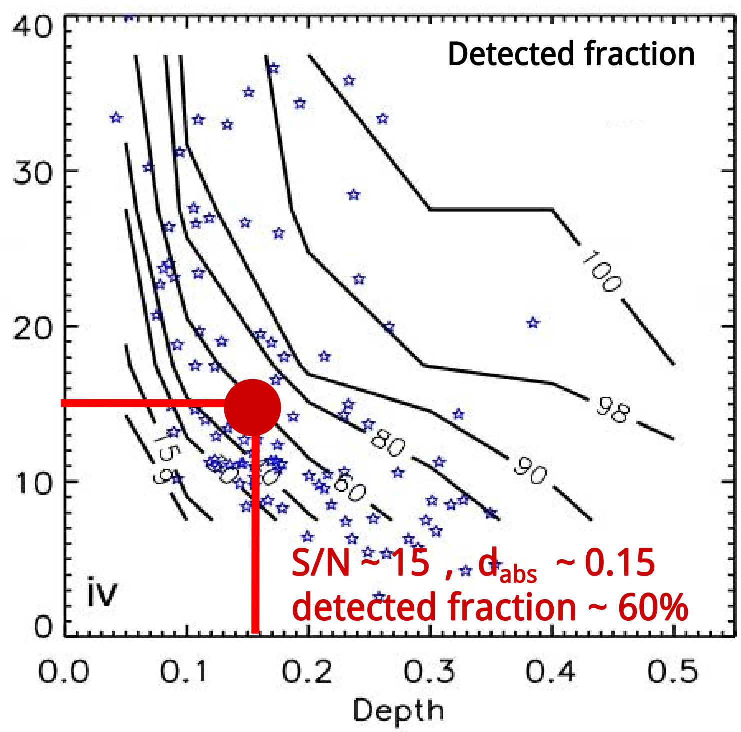



Examples of fits using the pair-matching method

**The pair-matching method is efficient for detecting weak absorption lines.**



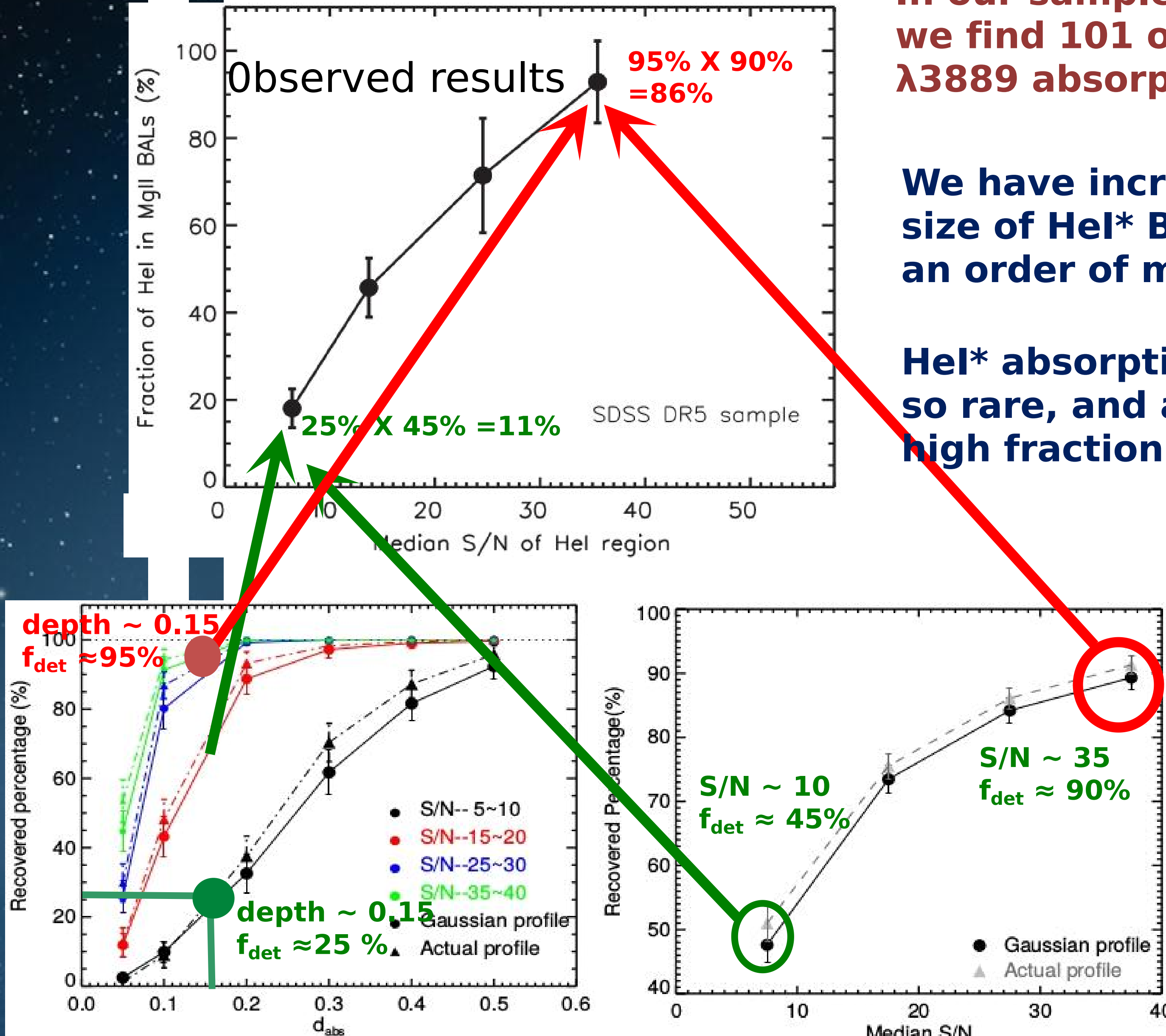



In our sample of 285 MgII BALs, we find 101 objects with HeI* λ3889 absorption line (~35%)

We have increased the sample size of HeI* BALs by more than an order of magnitude.

HeI* absorption lines are not so rare, and are found in a high fraction in MgII BALs.




The detected fraction is strongly dependent on spectral S/N.

Results from tests

# Applications of HeI* absorption

- We plan to enlarge the HeI* BAL sample to higher ( 1.35 < z > 2.25) and lower (z < 0.3) redshifts.

- We are now carrying out a mini-census looking for HeI* 10830 in z < 0.3 AGNs to find LoBAL QSOs. Low-z BAL QSOs are hard to detecte from the ground.

- Taking advantages of HeI* and other absorption lines, we can determine the $\dot{E}_k$ and $\dot{M}$ of the ionized AGN outflows for a large sample in $0 < z < 2.25$.

- For the low-z BAL sample, we can explore the connections between AGN outflows and host galaxies statistically.

- For the whole sample of both low-z and high-z, we will try to estimate the feedback powers of AGN outflows at different redshifts.

Thank you!