The Contribution of Quasar Absorption Outflows to AGN Feedback

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Special thanks for:

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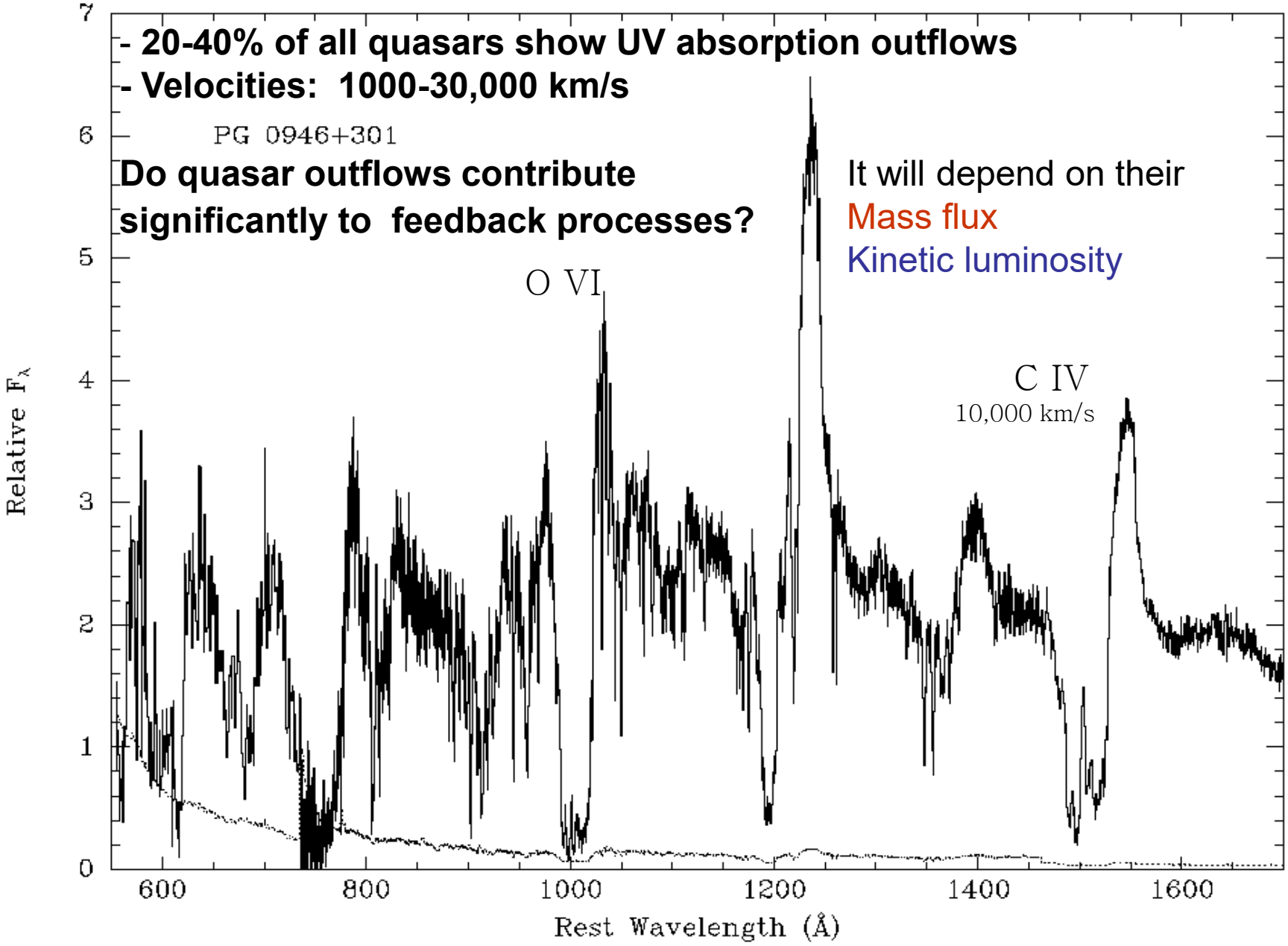
Doyee Byun (PhD student)

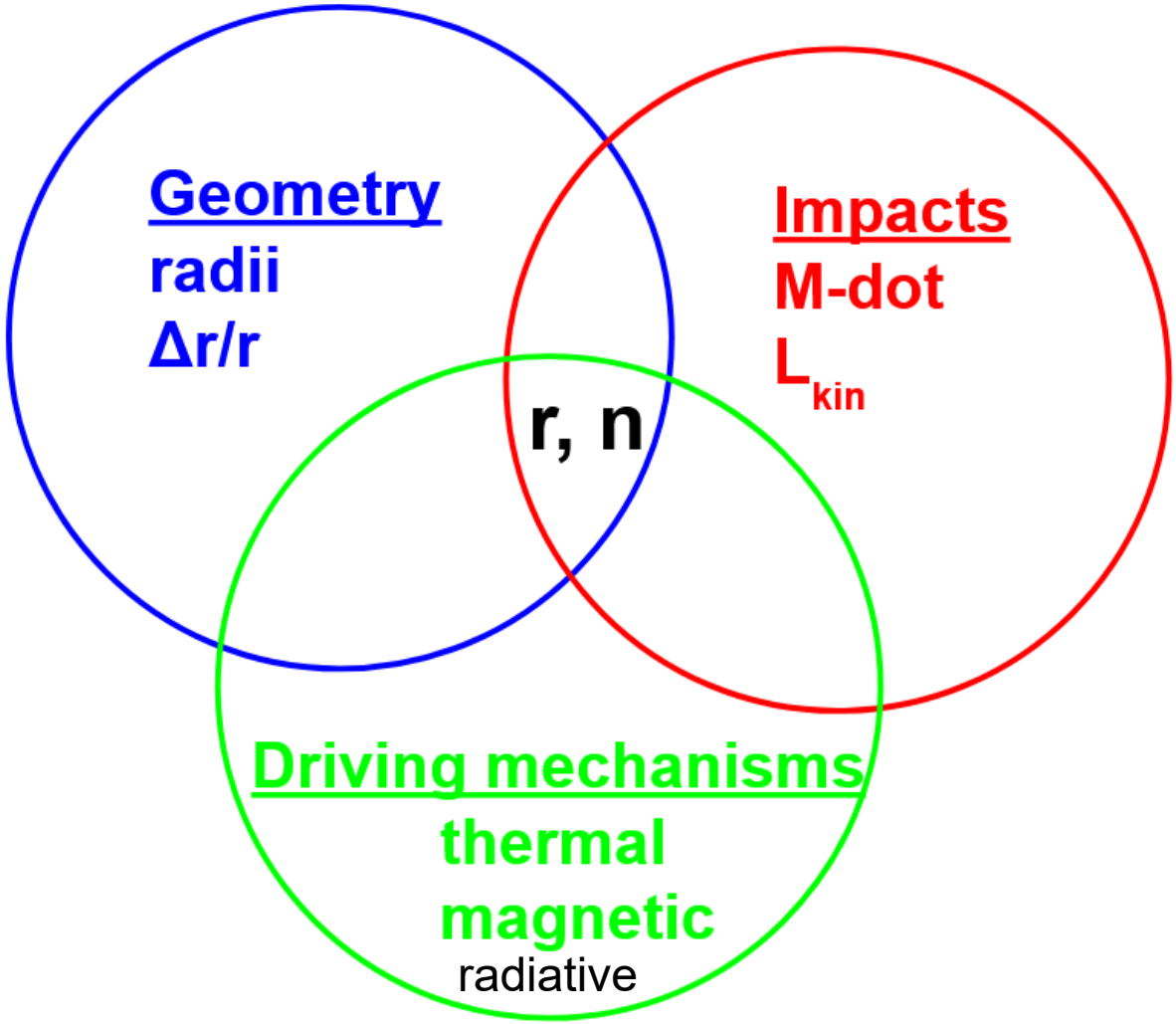
Who did most of the analysis

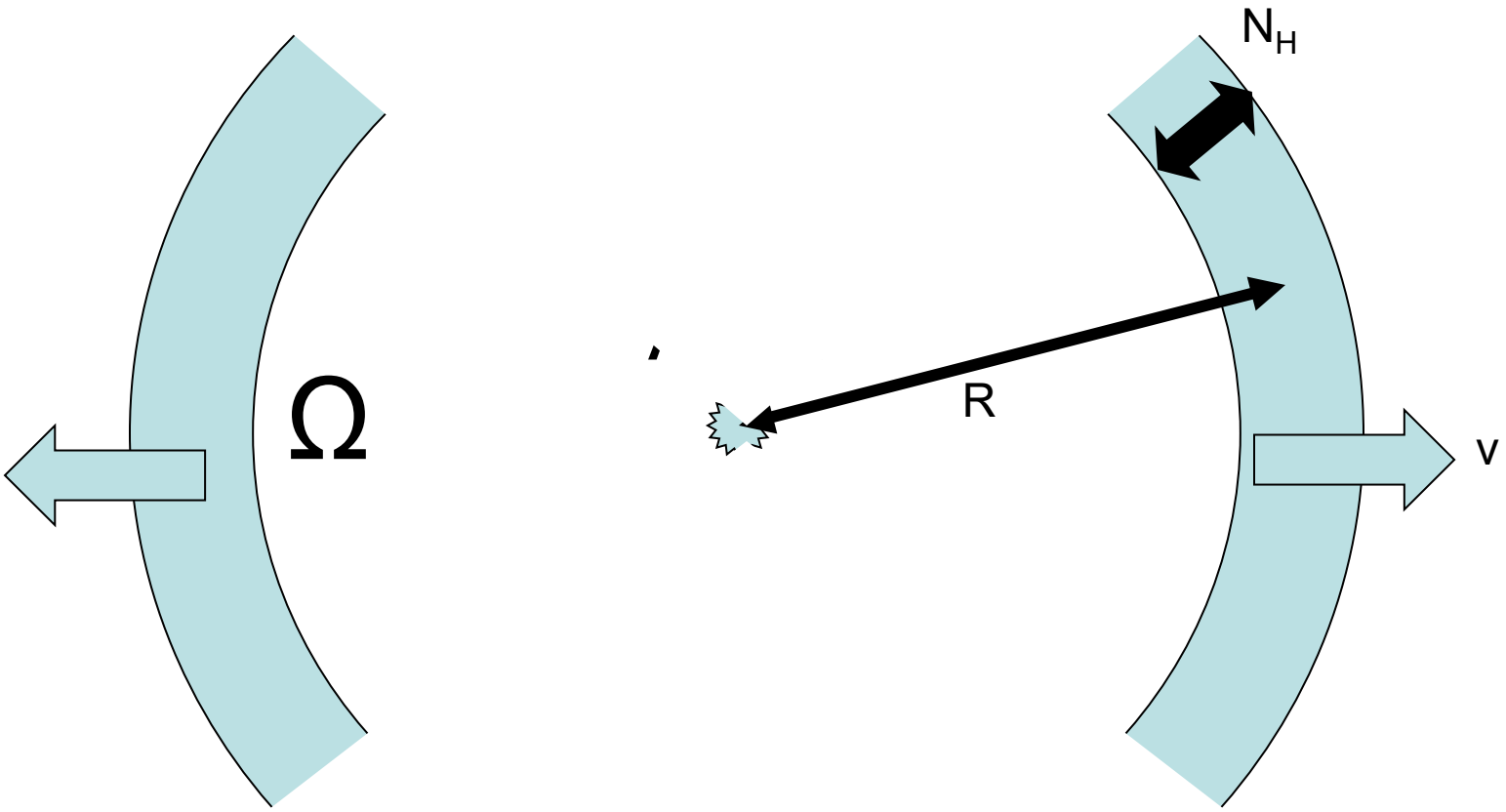
Jerry Kriss for UV insight and the HST/COS data product

Takeaway

- We study EUV absorption outflows in luminous quasars (where you expect strong AGN feedback).
- We are able to measure reliable and accurate distances (~100-1000 pc.) and N_H.
- Therefore, we measure reliable $\dot{E}_k$, often larger than 5% of L_{BOL}, enough to cause strong feedback.
- It is probable that most quasars have such outflows. Therefore, a typical luminous Quasar can provide major AGN feedback via absorption outflows.


- 20-40% of all quasars show UV absorption outflows
- Velocities: 1000-30,000 km/s
PG 0946+301
Do quasar outflows contribute significantly to feedback processes?
It will depend on their
Mass flux
Kinetic luminosity
O VI
C IV
10,000 km/s
Relative F_λ
Rest Wavelength (Å)
0
1
2
3
4
5
6
7
600
800
1000
1200
1400
1600

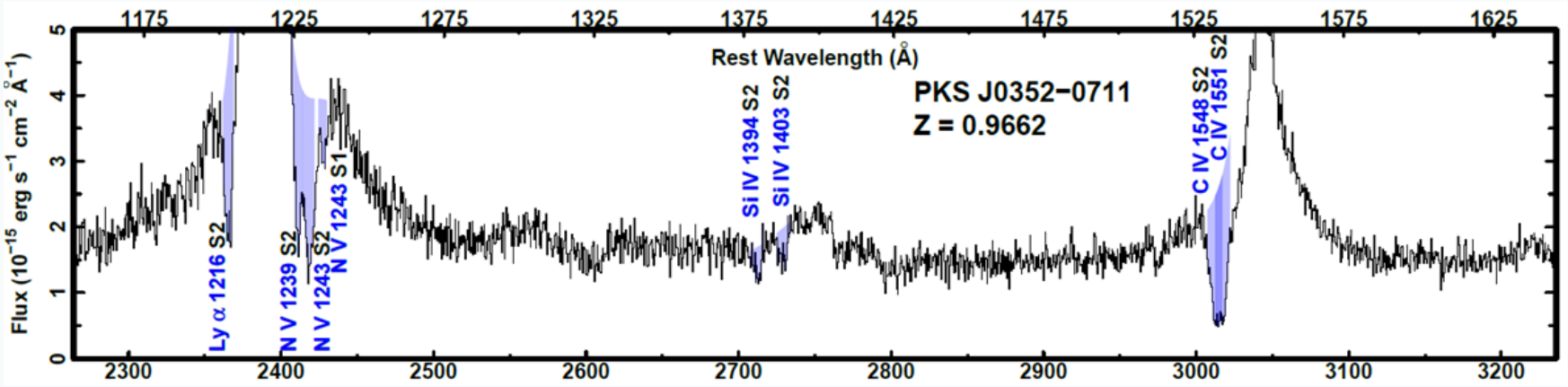

Geometry
radii
Δr/r
Impacts
M-dot
L_{kin}
r, n
Driving mechanisms
thermal
magnetic
radiative

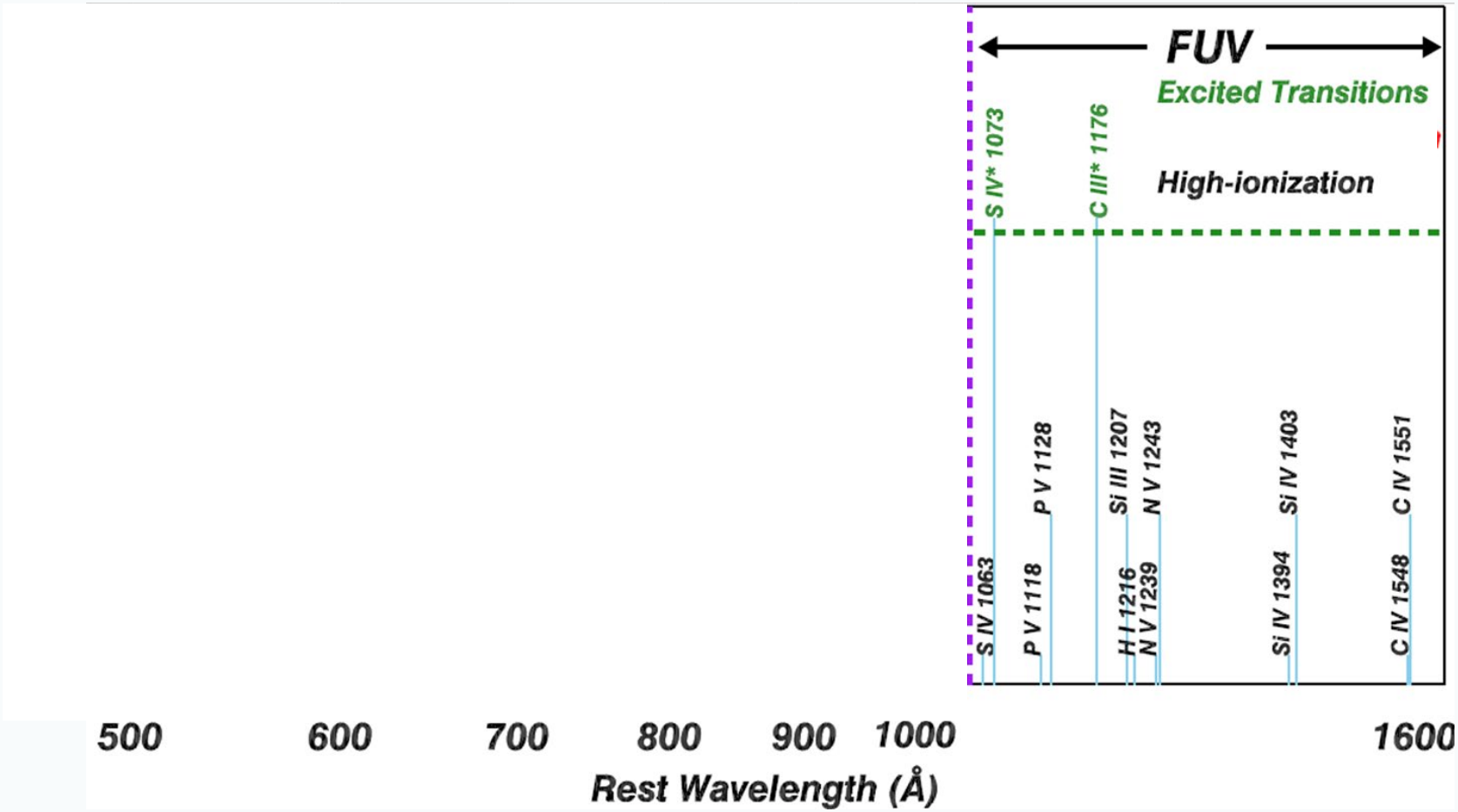

Ω
N_H
R
v

Mass flux and Kinetic luminosity of absorption outflows

$$M \simeq 4\pi\Omega R^2 N_H \mu m_p \qquad \dot{M} \equiv \frac{M}{(R/v)} = 4\pi\Omega R N_H \mu m_p v \qquad \dot{E}_k = \frac{1}{2}\dot{M}v^2$$

$$\dot{E}_k = \frac{1}{2}\dot{m}v^2 \approx 2\pi\Omega R N_H 1.4 m_p v^3$$


Rest Wavelength (Å)
PKS J0352−0711
Z = 0.9662
Flux (10^{-15} erg s^{-1} cm^{-2} Å^{-1})
Ly α 1216 S2
N V 1239 S2
N V 1243 S2
N V 1243 S1
Si IV 1394 S2
Si IV 1403 S2
C IV 1548 S2
C IV 1551 S2

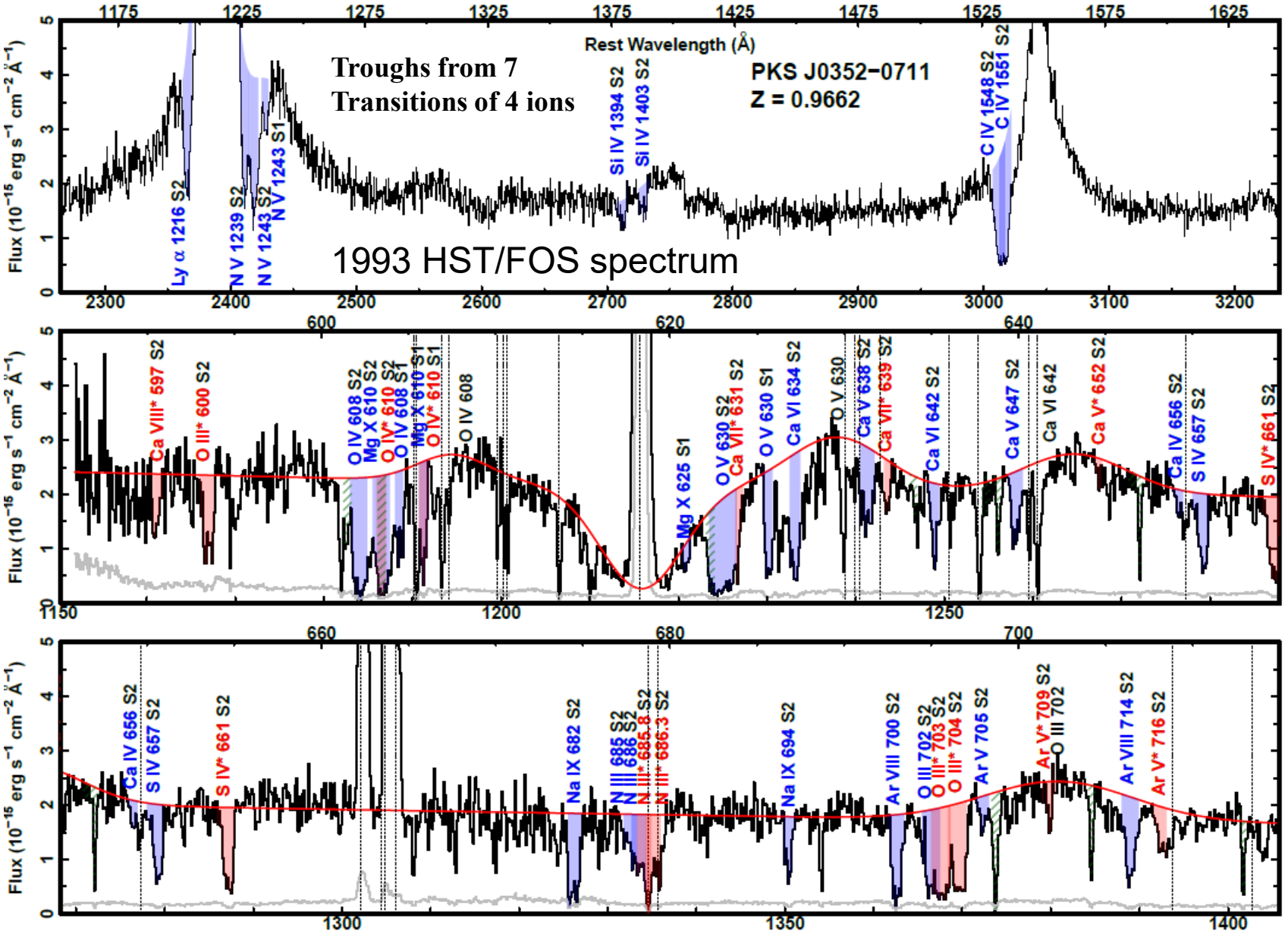

FUV
Excited Transitions
High-ionization
S IV* 1073
C III* 1176
S IV 1063
P V 1118
P V 1128
H I 1216
Si III 1207
N V 1239
N V 1243
Si IV 1394
Si IV 1403
C IV 1548
C IV 1551
Rest Wavelength (Å)

In order to realize the science-potential of EUV500 data for quasar outflows, we executed the first dedicated survey. This spectroscopic survey program (HST GO 14777, PI: Arav) observed ten quasars with known EUV500 outflows at redshift z $\sim$ 1. Each object was observed for 4 orbits, two each with COS gratings G130M and G160M (the objects and their observations are listed

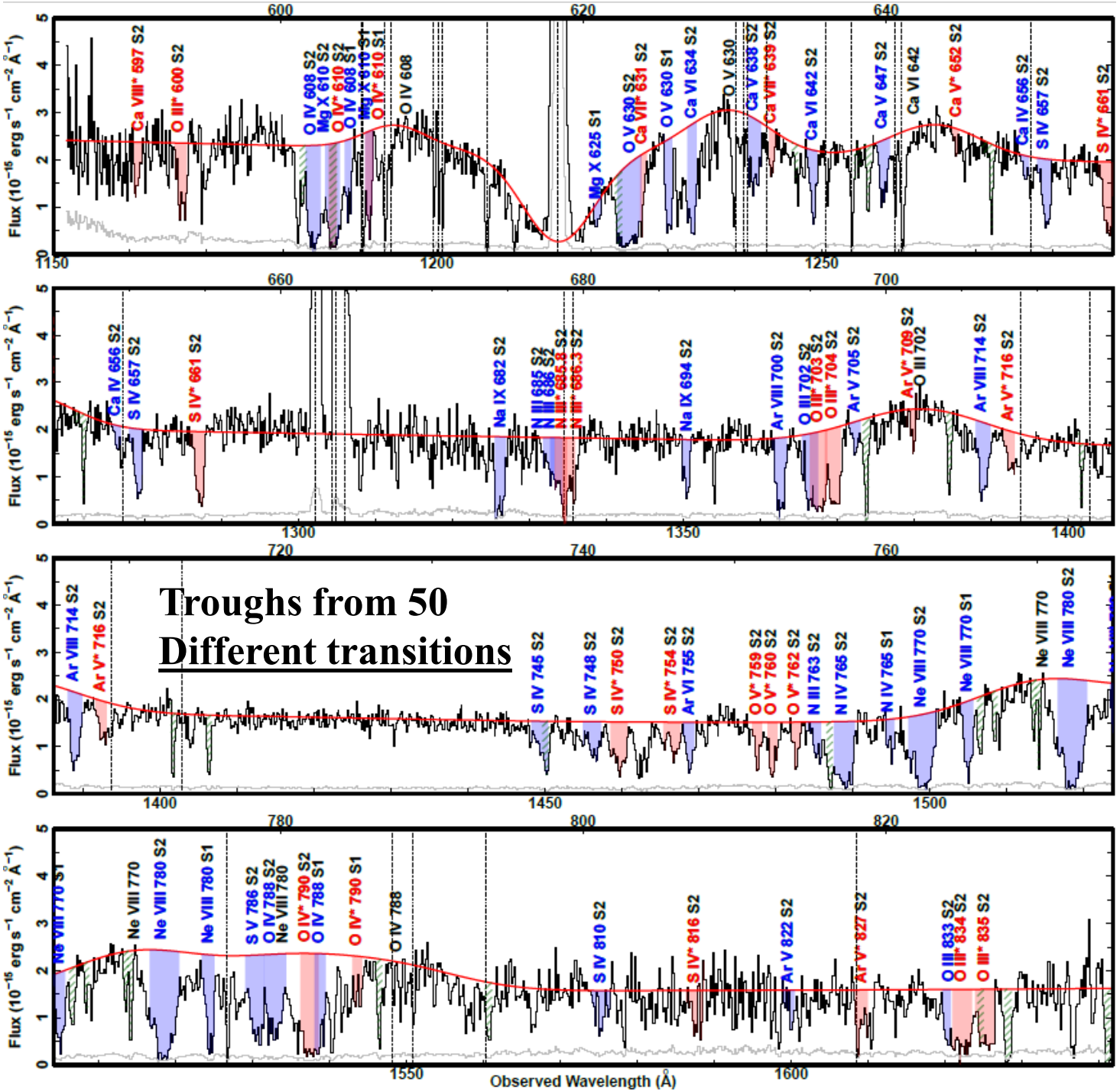
Sample selection

The sample is representative of 90% of all observed BALs

- The parent populations was made from ~1000 HST spectra of quasars that were obtain for intervening absorption studies. So the parent population is not biased towards any type or characteristics of quasar outflows.
- An outflow was identified by matching at least two troughs with the same velocity that arise from resonance transitions of either the high-ionization phase (HP; e.g., O iv, N iv, and S iv) or the VHP (i.e.,Ne viii and Mg x). This identification scheme prevented biases towards a particular phase (either phase was chosen), a particular **R** (searched for only resonance lines), or a particular velocity (identified outflows at any velocity).
- None of the outflows show low ionization species (e.g., Mg II, Si II), and all show high-ionization ionization species (e.g., O iv, N iv, and S iv). Therefore, they are representative of HiBALs, which are 90% of all observed BALs

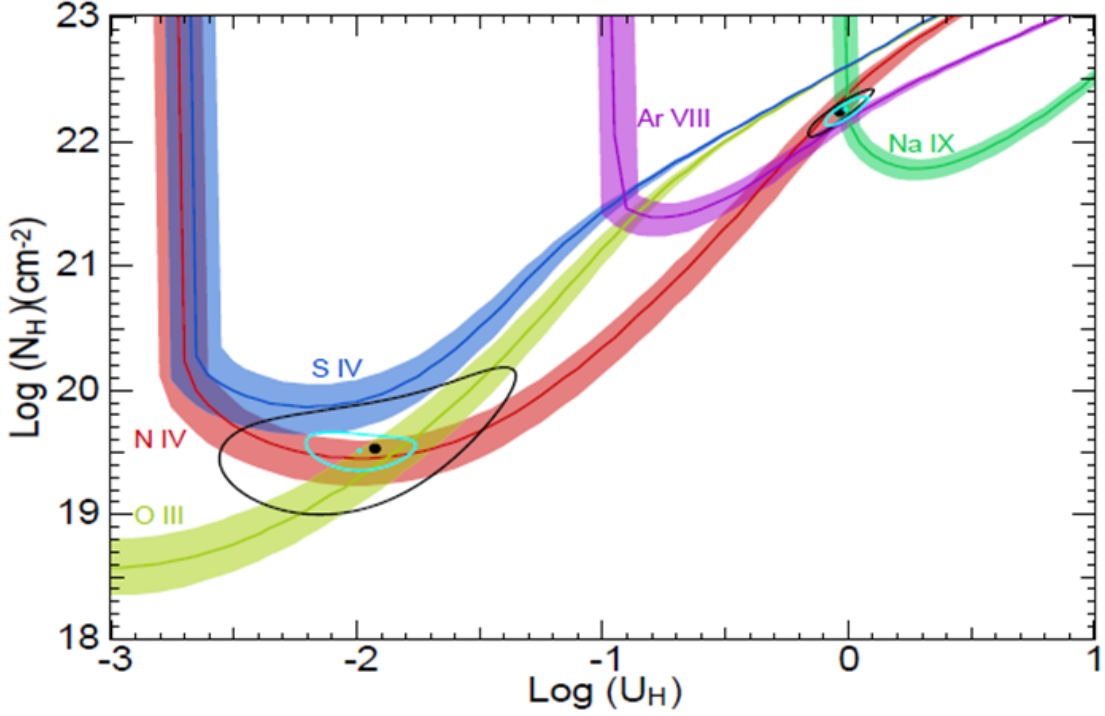

Troughs from 7
Transitions of 4 ions
PKS J0352−0711
Z = 0.9662
Rest Wavelength (Å)
Flux (10^{-15} erg s^{-1} cm^{-2} Å^{-1})
Ly α 1216 S2
N V 1239 S2
N V 1243 S2
N V 1243 S1
Si IV 1394 S2
Si IV 1403 S2
C IV 1548 S2
C IV 1551 S2
1993 HST/FOS spectrum
Ca VIII* 597 S2
O III* 600 S2
O IV 608 S2
Mg X 610 S2
O IV* 610 S2
O IV 608 S1
Mg X 610 S1
O IV* 610 S1
O IV 608
Mg X 625 S1
O V 630 S2
Ca VII* 631 S2
O V 630 S1
Ca VI 634 S2
O V 630
Ca V 638 S2
Ca VII* 639 S2
Ca VI 642 S2
Ca V 647 S2
Ca VI 642
Ca V* 652 S2
Ca IV 656 S2
S IV 657 S2
S IV* 661 S2
Ca IV 656 S2
S IV 657 S2
S IV* 661 S2
Na IX 682 S2
N III 685 S2
N III 686 S2
N III* 685.8 S2
N III* 686.3 S2
Na IX 694 S2
Ar VIII 700 S2
O III 702 S2
O III* 703 S2
O III* 704 S2
Ar V 705 S2
Ar V* 709 S2
O III 702
Ar VIII 714 S2
Ar V* 716 S2
2017 HST/COS (G160M and G130M) spectrum

2017 HST/COS (G160M and G130M) spectrum

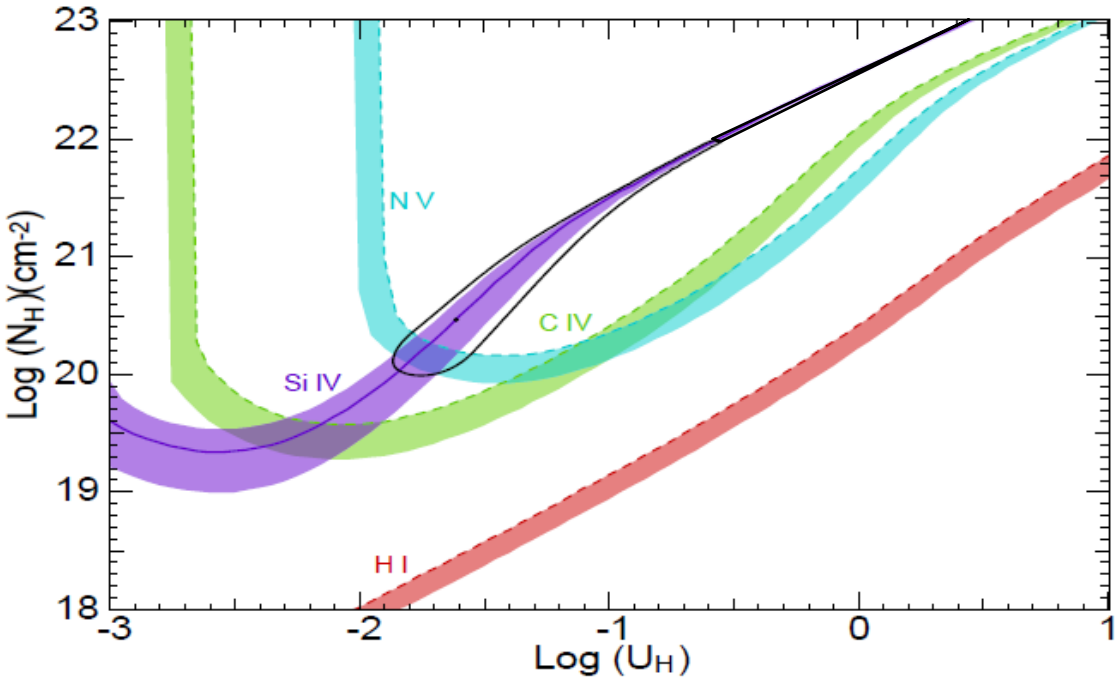


HST/COS data

2 ionization phases:
The very-high-phase
Caries 99% of the total N_H



λ_{rest}>1150 A data



Measuring the distance (*R*) from the central source to the outflow, and the kinetic luminosity

$$U_H \equiv \frac{Q_H}{4\pi R^2 c n_e} \quad \Rightarrow \quad R = \sqrt{\frac{Q_H}{4\pi c n_e U_H}}$$

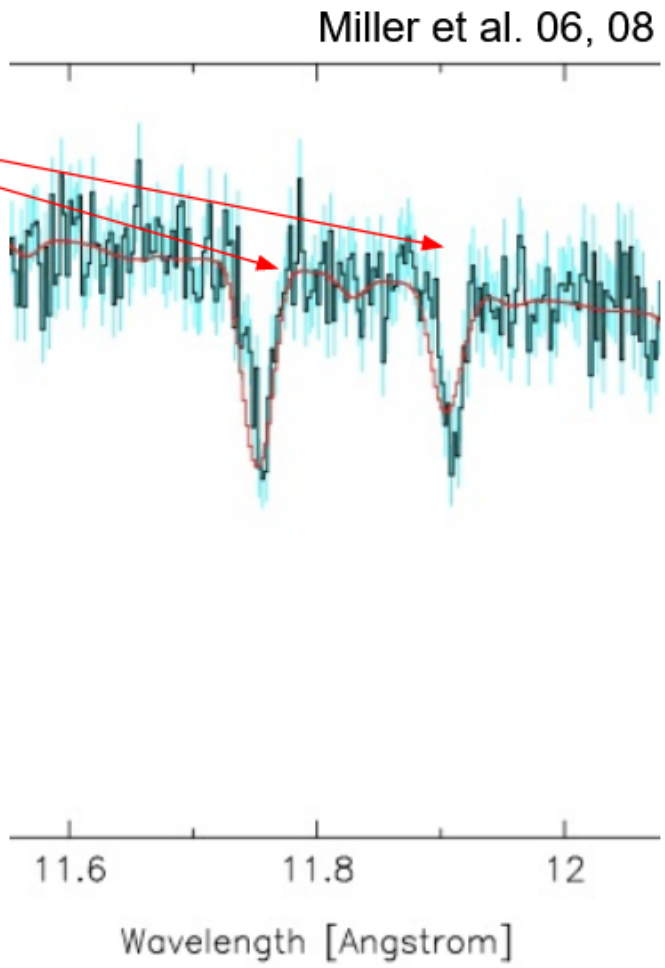
$$\dot{E}_k = \frac{1}{2}\dot{m}v^2 \approx 2\pi\Omega R N_H 1.4 m_p v^3$$

Density from metastable lines

Fe XXII lines in GRO J1655-40

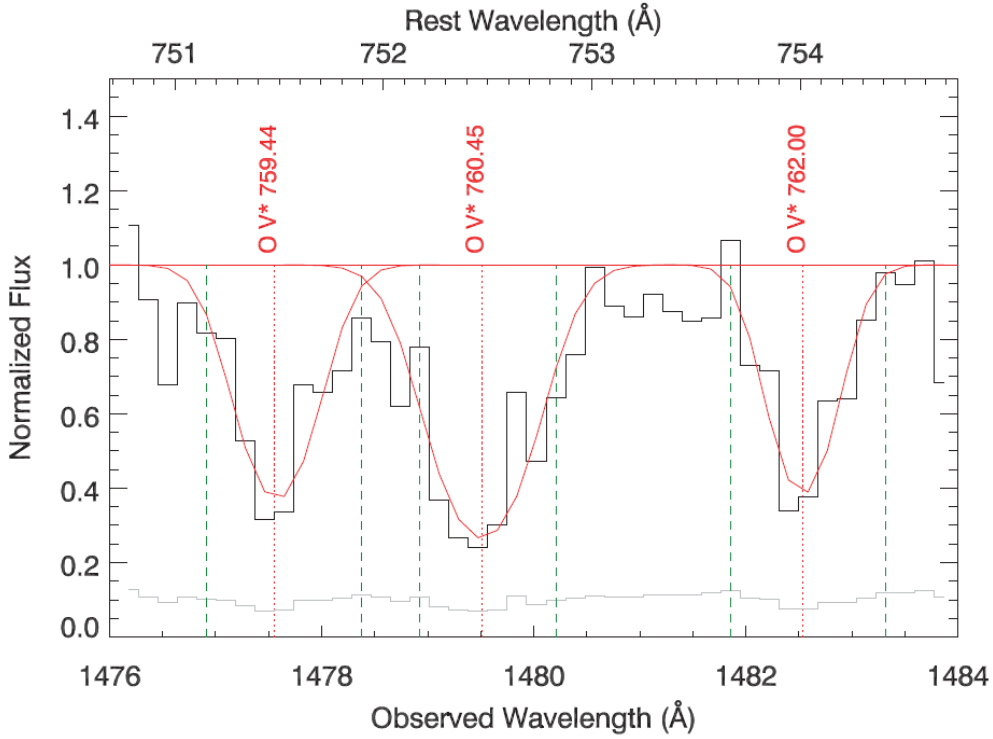
$n \sim 10^{14}$ cm^{-3}

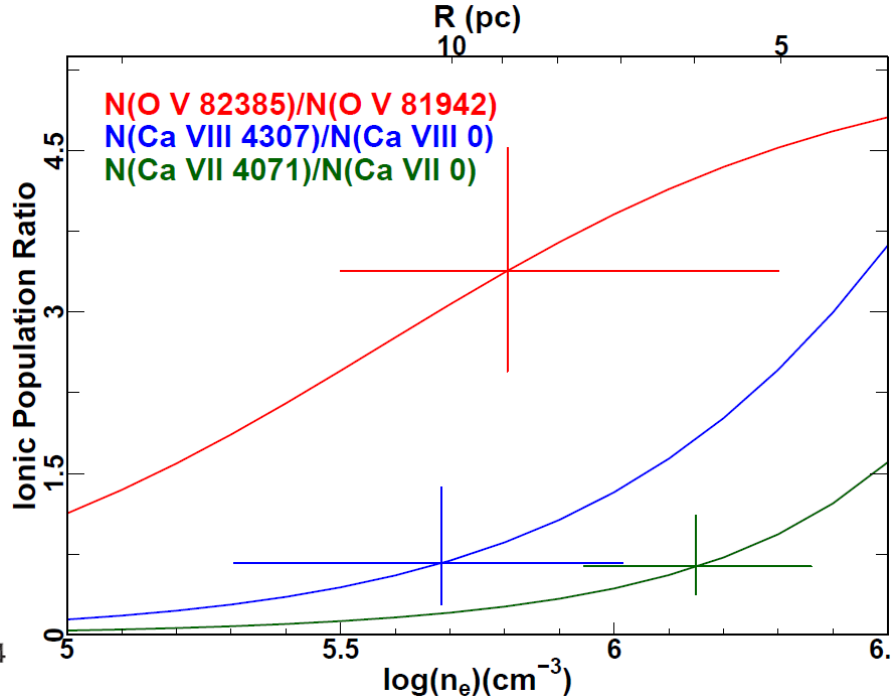
$r = (L/n\xi)^{½}$



What about *R*?

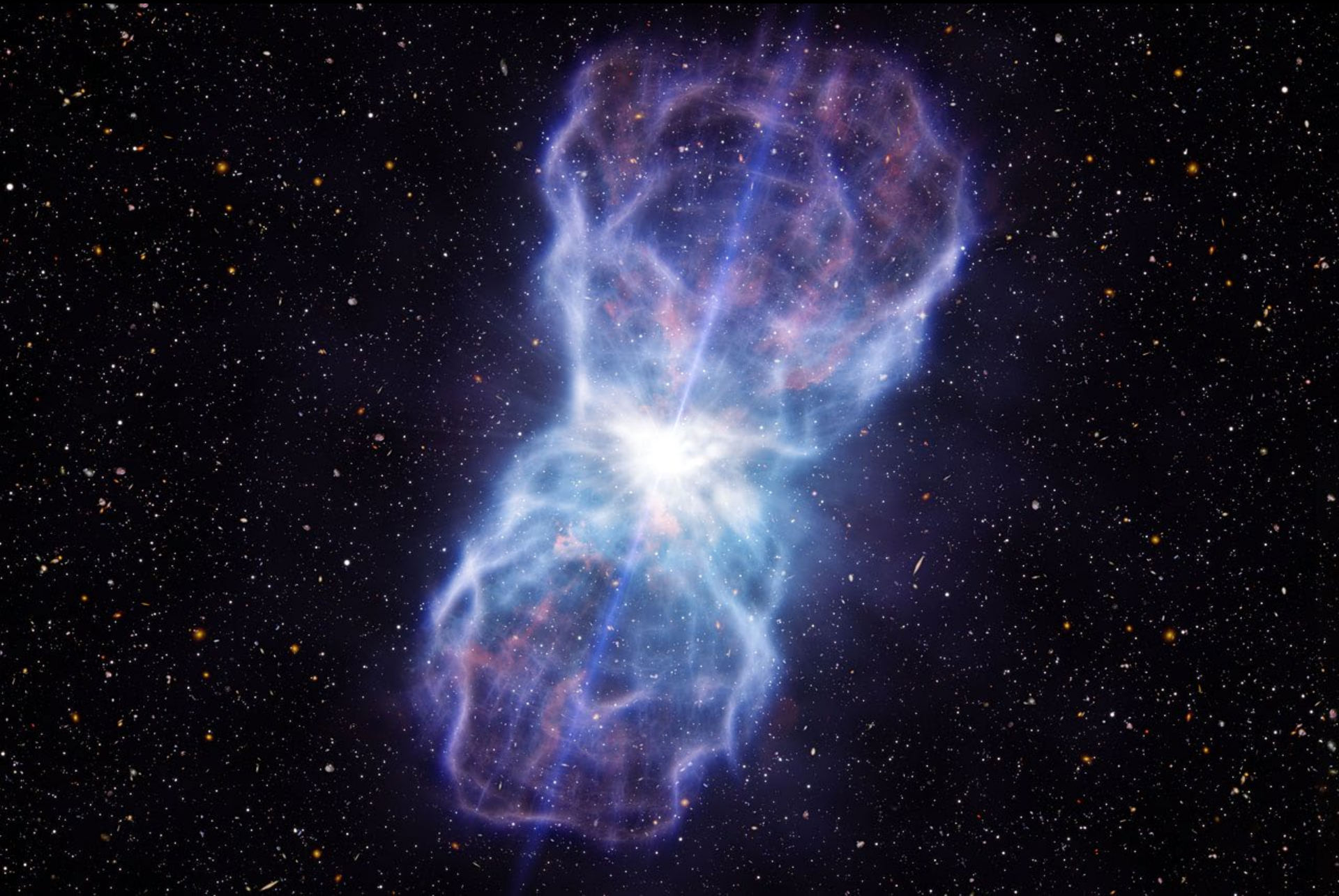
HST/COS spectra of PKS J0352-0711:
Discovery of absorption troughs from: O V*, Ca VII, Ca VII*, Ca VIII, Ca VIII*

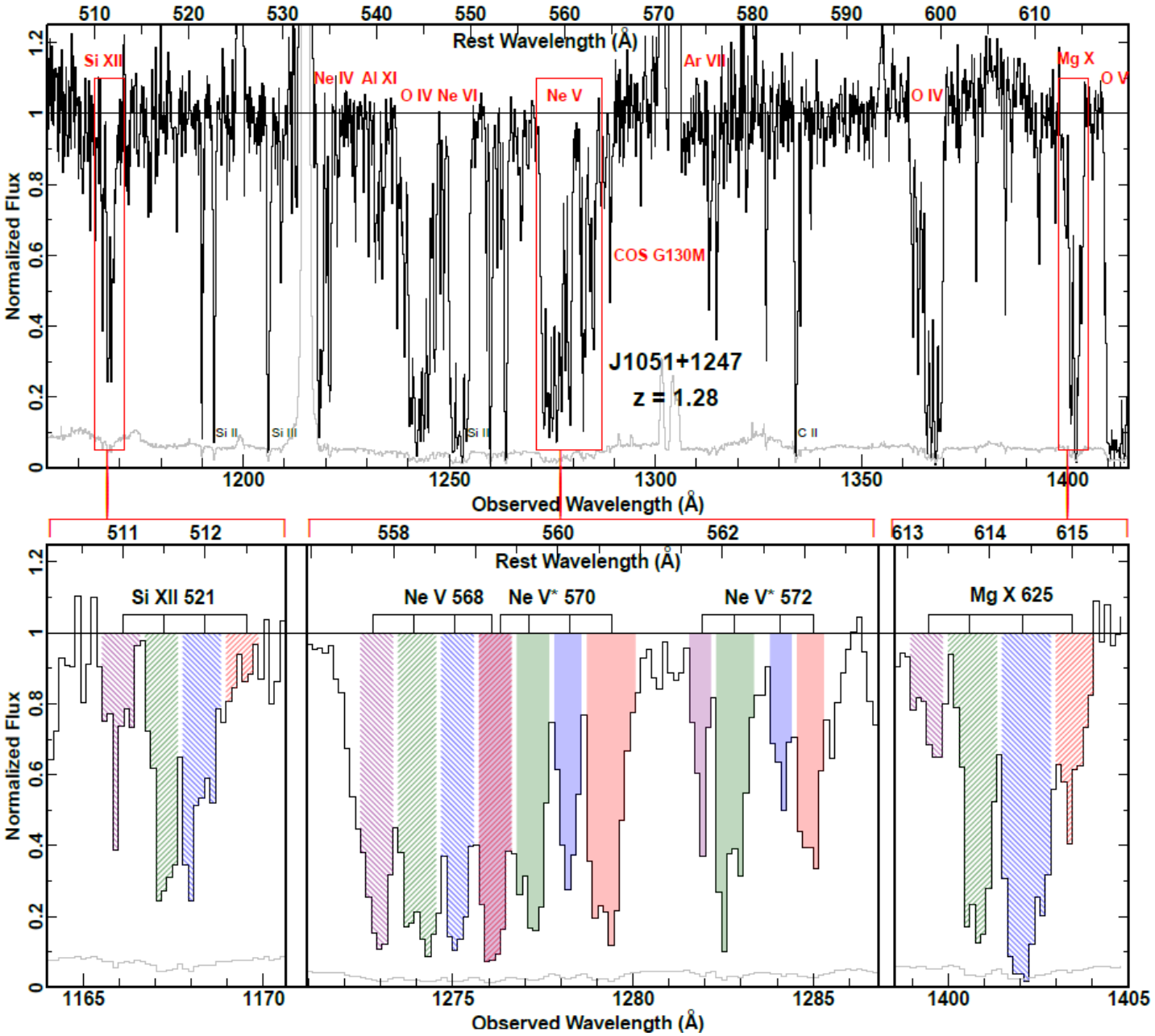


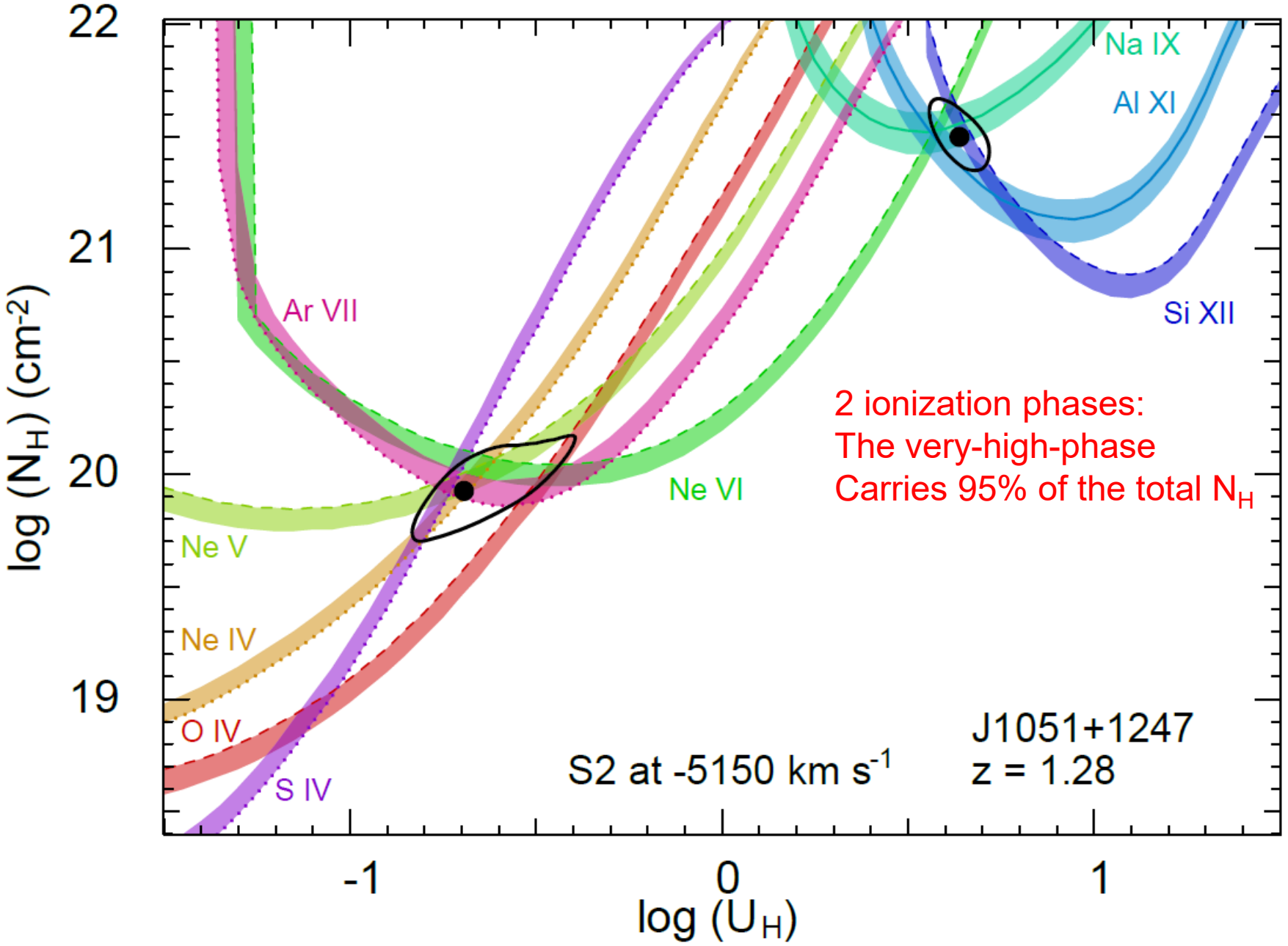


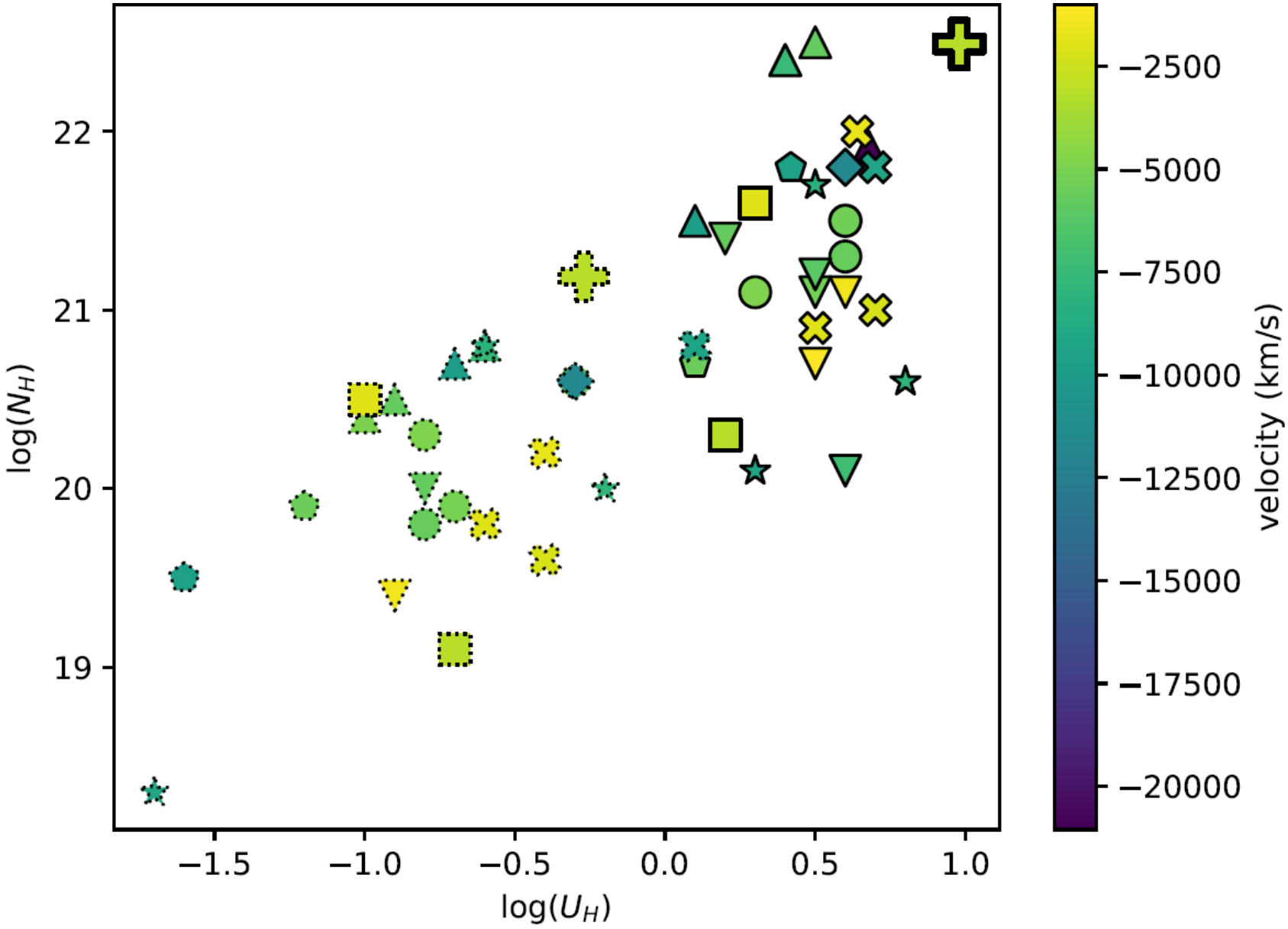
5) These findings were partially enabled by the first detection of absorption troughs from previously unseen transitions of O IV*, O V*, Ar VI, Ne V*, Ne VI*, Ca IV, Ca V, Ca V*, Ca VI, Ca VII, Ca VII*, Ca VIII and Ca VIII*.

One of the four most energetic outflows ever recorded

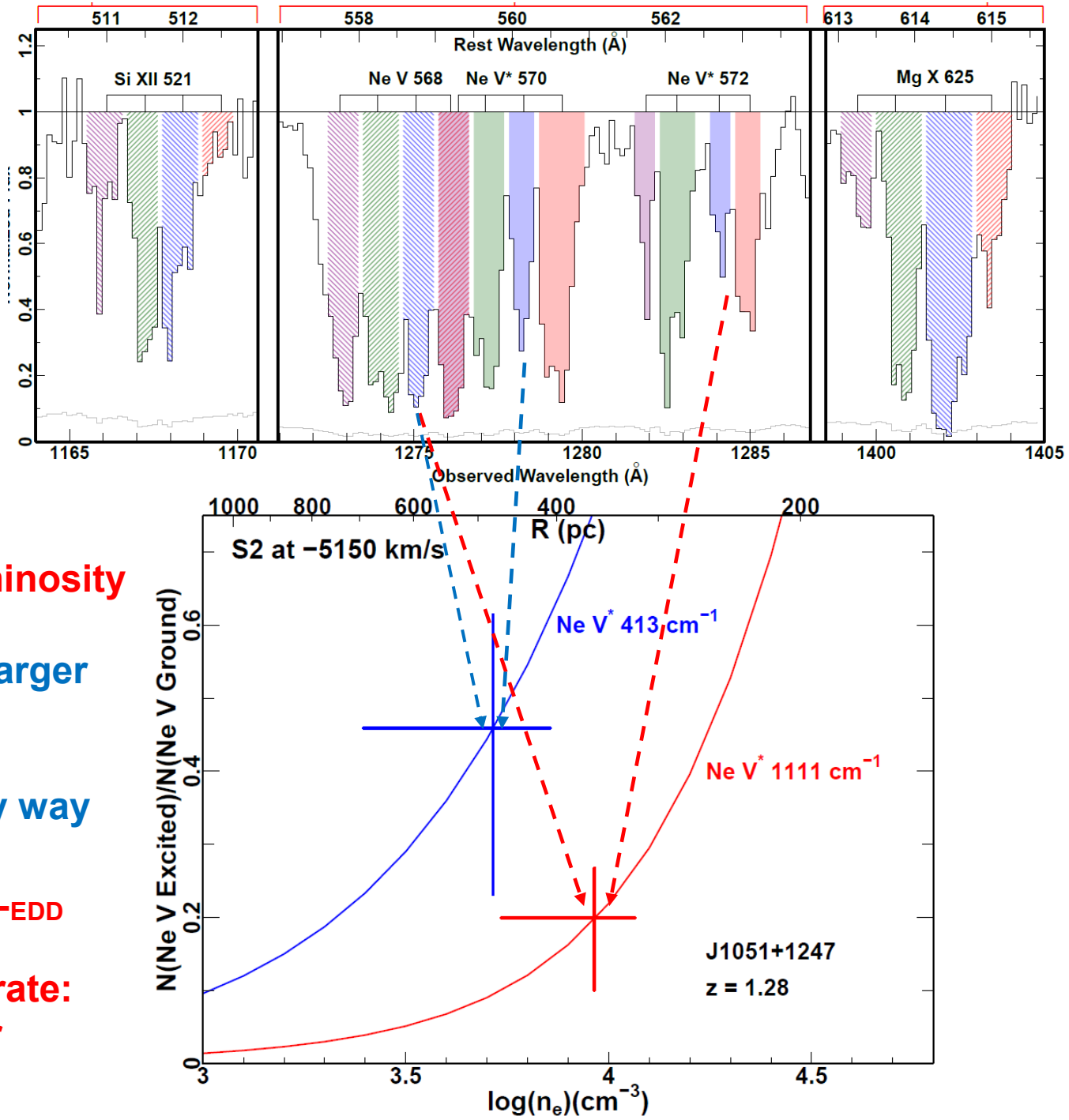



Rest Wavelength (Å)
Si XII
Ne IV Al XI
O IV Ne VI
Ne V
Ar VII
O IV
Mg X
O V
COS G130M
J1051+1247
z = 1.28
Si II
Si II
Si II
C II
Normalized Flux
Observed Wavelength (Å)
Si XII 521
Ne V 568
Ne V* 570
Ne V* 572
Mg X 625


22
21
20
19
log (N_H) (cm^-2)
-1
0
1
log (U_H)
Na IX
Al XI
Si XII
Ar VII
Ne VI
Ne V
Ne IV
O IV
S IV
2 ionization phases:
The very-high-phase
Carries 95% of the total N_H
S2 at -5150 km s^-1
J1051+1247
z = 1.28


22
21
20
19
log(N_H)
−1.5
−1.0
−0.5
0.0
0.5
1.0
log(U_H)
−2500
−5000
−7500
−10000
−12500
−15000
−17500
−20000
velocity (km/s)

Byun+ 2023



R = 400 pc

Kinetic luminosity
10^{46} ergs/s
100 times larger than the luminosity of the Milky way

Or 10% of L_{EDD}

Mass flow rate:
1000 $M_{\odot}$ /yr

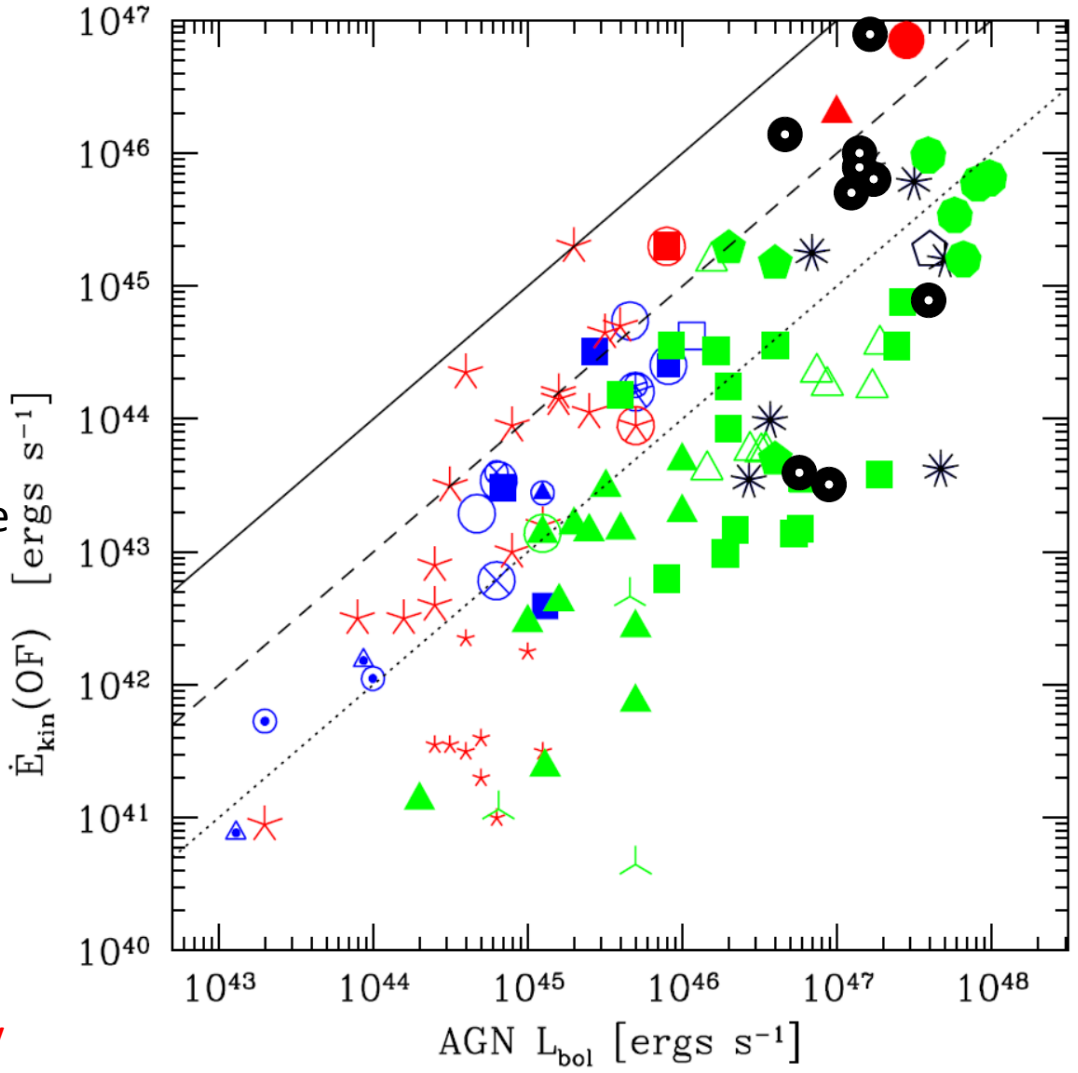
Takeaway 2

Broad Absorption Lines (BAL) outflows:

a) Comprise more than half of the most energetic quasar outflows (see Figure), and the majority of these have enough kinetic luminosity to produce strong feedback effects.

b) The observed sample is representative for the majority of absorption outflows. Therefore, these results can be extrapolated to the majority of objects showing BAL outflows.

c) Assuming that all quasars have absorption outflows, we conclude that most luminous quasars produce outflows that can contribute significantly to AGN feedback.



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