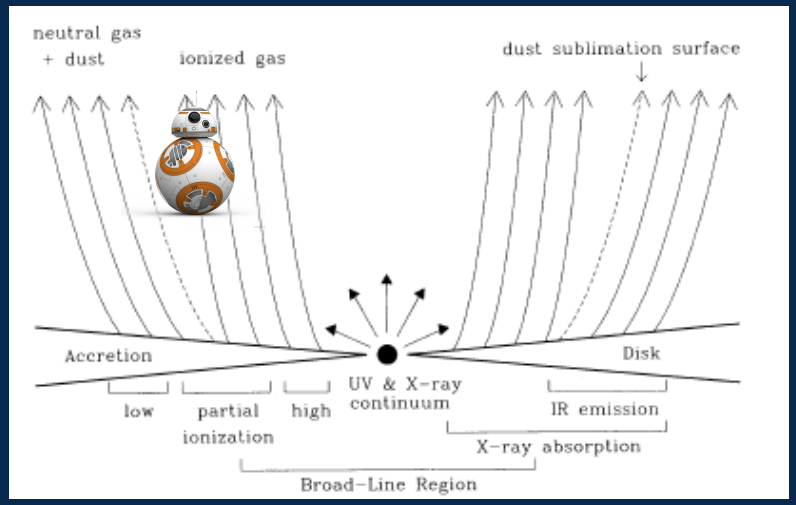
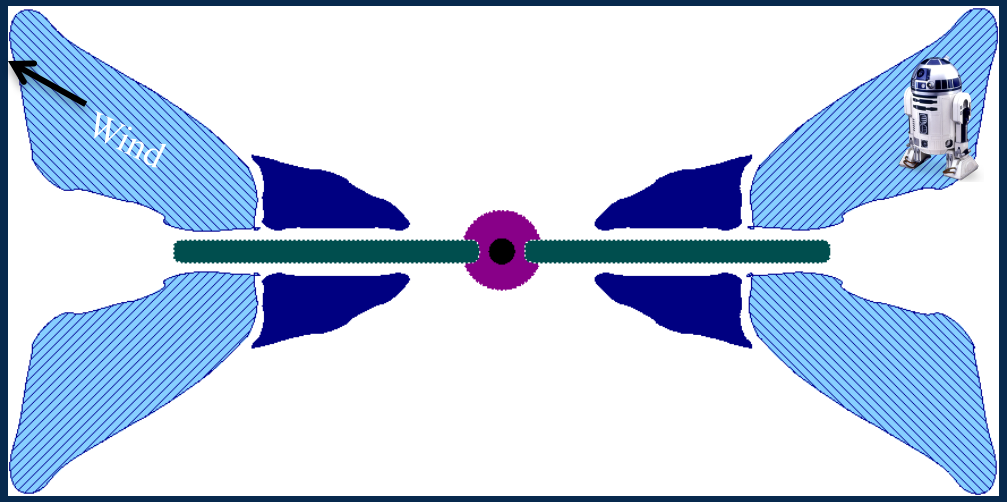
These aren't the BALs you're looking for (and other short stories)

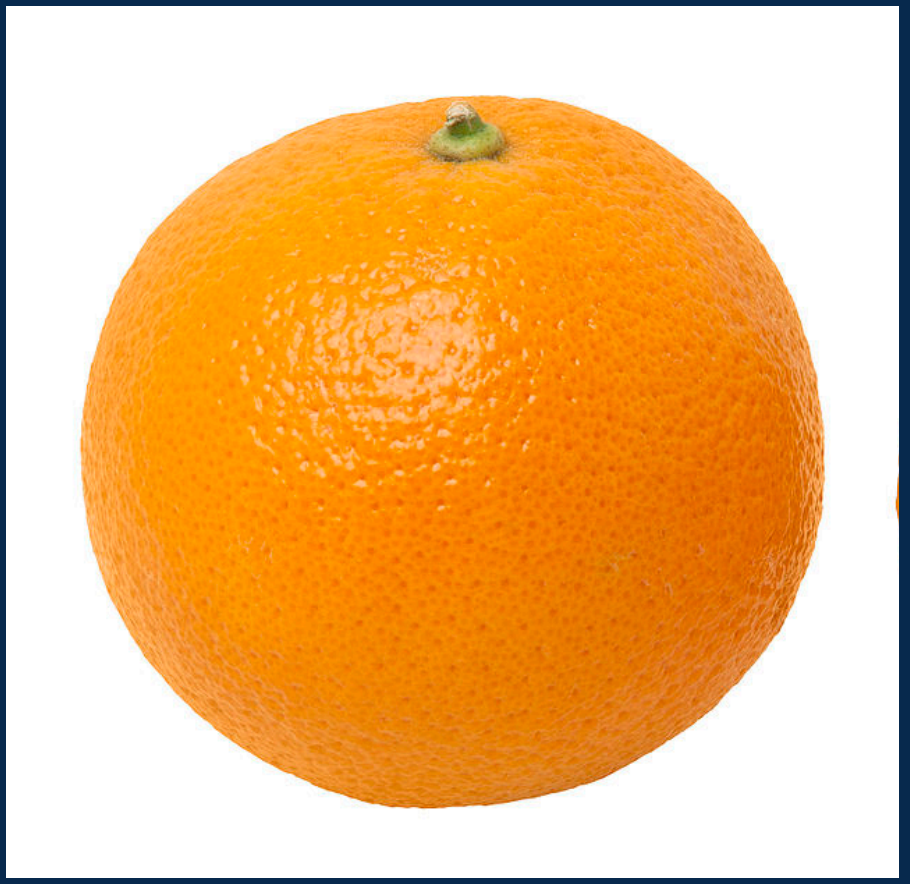
Gordon Richards
Drexel University





With thanks to Paul Hewett and Liam Coatman (IoA, Cambridge), Sarah Gallagher (UWO), Karen Leighly (OU), Robyn Smith, Jack O'Brien and Rob Stone (Drexel)

Apples vs. or incl. Oranges?



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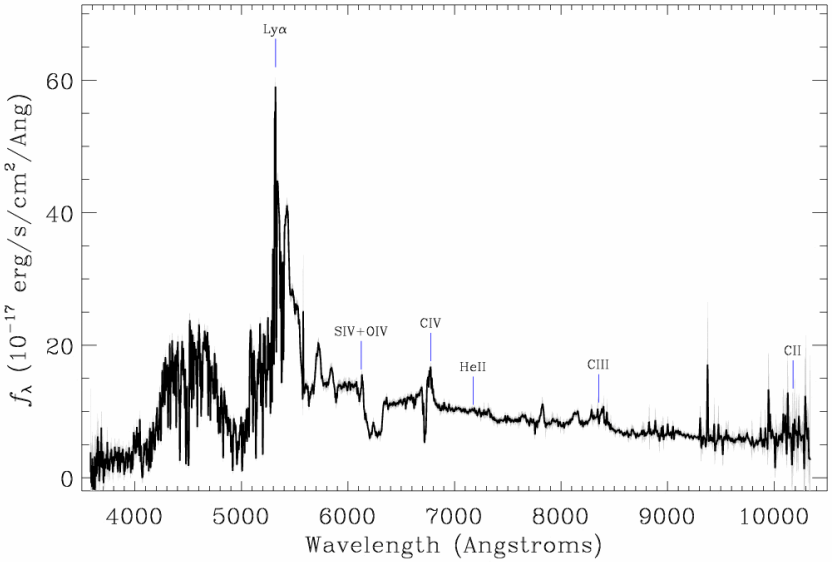

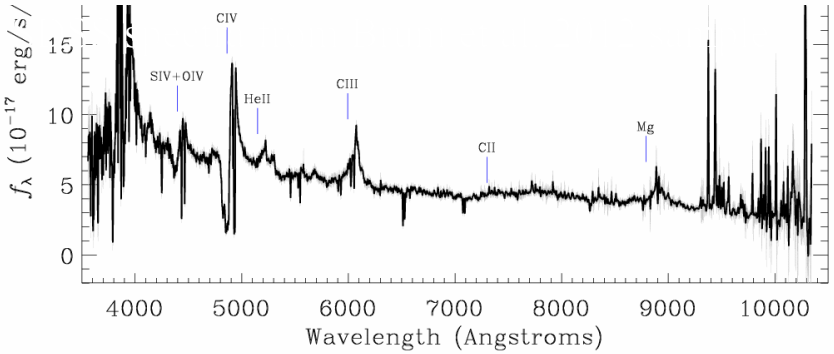

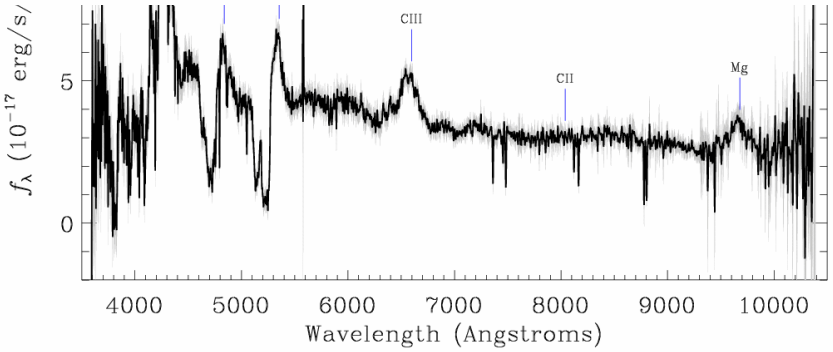

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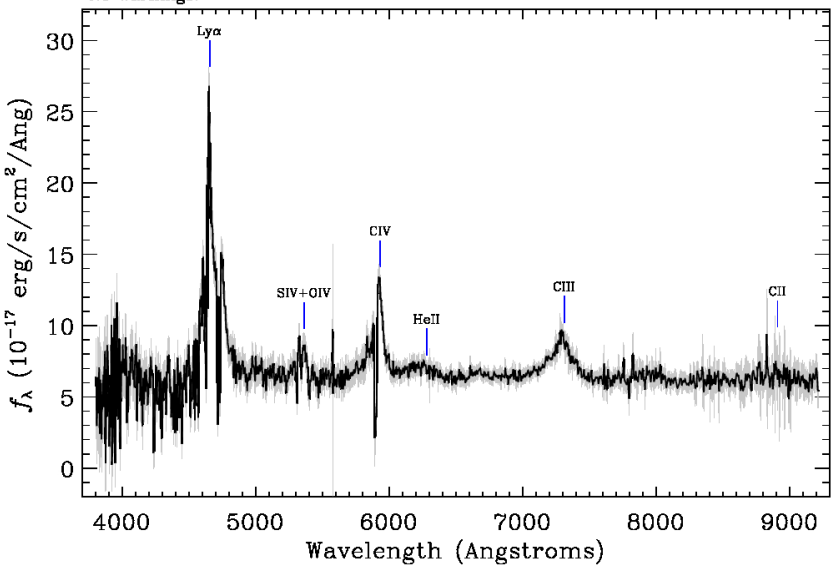
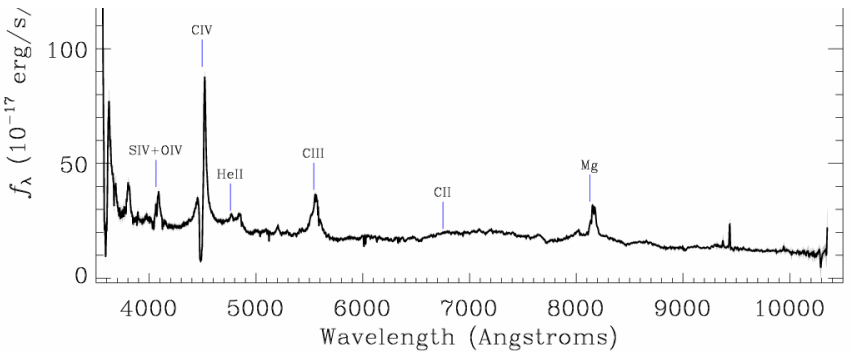
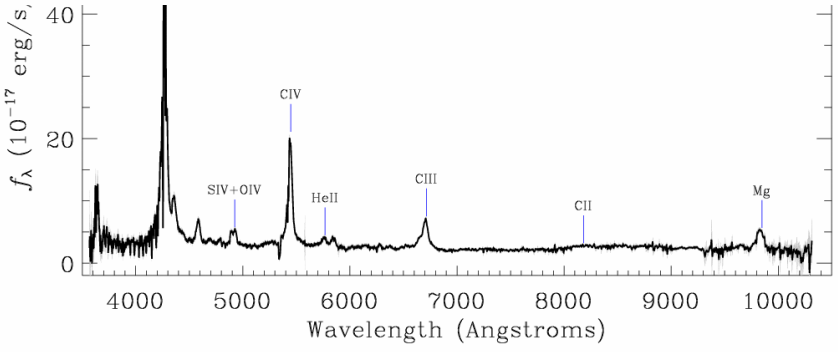






Modified BAL Definition

A CATALOG OF BROAD ABSORPTION LINE QUASARS FROM THE SLOAN DIGITAL SKY SURVEY THIRD DATA RELEASE

Jonathan R. Trump,[1,2] Patrick B. Hall,[3,4] Timothy A. Reichard,[5] Gordon T. Richards,[3,5]
Donald P. Schneider,[1] Daniel E. Vanden Berk,[1] Gillian R. Knapp,[3] Scott F. Anderson,[6]
Xiaohui Fan,[2] J. Brinkman,[7] S. J. Kleinman,[8] and Atsuko Nitta[8]

Received 2005 December 15; accepted 2006 March 1

ABSTRACT

We present a total of 4784 unique broad absorption line quasars from the Sloan Digital Sky Survey Third Data Release. An automated algorithm was used to match a continuum to each quasar and to identify regions of flux at least 10% below the continuum over a velocity range of at least 1000 km s^{-1} in the C IV and Mg II absorption regions. The model continuum was selected as the best-fit match from a set of template quasar spectra binned in luminosity, emission line width, and redshift, with the power-law spectral index and amount of dust reddening as additional free parameters. We characterize our sample through the traditional "balnicity" index and a revised absorption index, as well as through parameters such as the width, outflow velocity, fractional depth, and number of troughs. From a sample of 16,883 quasars at $1.7 \leq z \leq 4.38$, we identify 4386 (26.0%) quasars with broad C IV absorption, of which 1756 (10.4%) satisfy traditional selection criteria. From a sample of 34,973 quasars at $0.5 \leq z \leq 2.15$, we identify 457 (1.31%) quasars with broad Mg II absorption, 191 (0.55%) of which satisfy traditional selection criteria. We also provide a supplementary list of 39 visually identified $z > 4.38$ quasars with broad C IV absorption. We find that broad absorption line quasars may have broader emission lines on average than other quasars.

The Astrophysical Journal Supplement Series, 194:45 (21pp), 2011 June doi:10.1088/0067-0049/194/2/45

A CATALOG OF QUASAR PROPERTIES FROM SLOAN DIGITAL SKY SURVEY DATA RELEASE 7

Yue Shen[1], Gordon T. Richards[2], Michael A. Strauss[3], Patrick B. Hall[4], Donald P. Schneider[5], Stephanie Snedden[6],
Dmitry Bizyaev[6], Howard Brewington[6], Viktor Malanushenko[6], Elena Malanushenko[6],
Dan Oravetz[6], Kaike Pan[6], and Audrey Simmons[6]
[1] Harvard-Smithsonian Center for Astrophysics, 60 Garden St., MS-51, Cambridge, MA 02138, USA
[2] Department of Physics, Drexel University, 3141 Chestnut Street, Philadelphia, PA 19104, USA
[3] Princeton University Observatory, Princeton, NJ 08544, USA
[4] Department of Physics & Astronomy, York University, 4700 Keele St., Toronto, ON, M3J 1P3, Canada
[5] Department of Astronomy and Astrophysics, 525 Davey Laboratory, Pennsylvania State University, University Park, PA 16802, USA
[6] Apache Point Observatory, Sunspot, NM, 88349, USA
Received 2010 June 26; accepted 2011 May 1; published 2011 June 2

Associated Absorption = Ouflow?

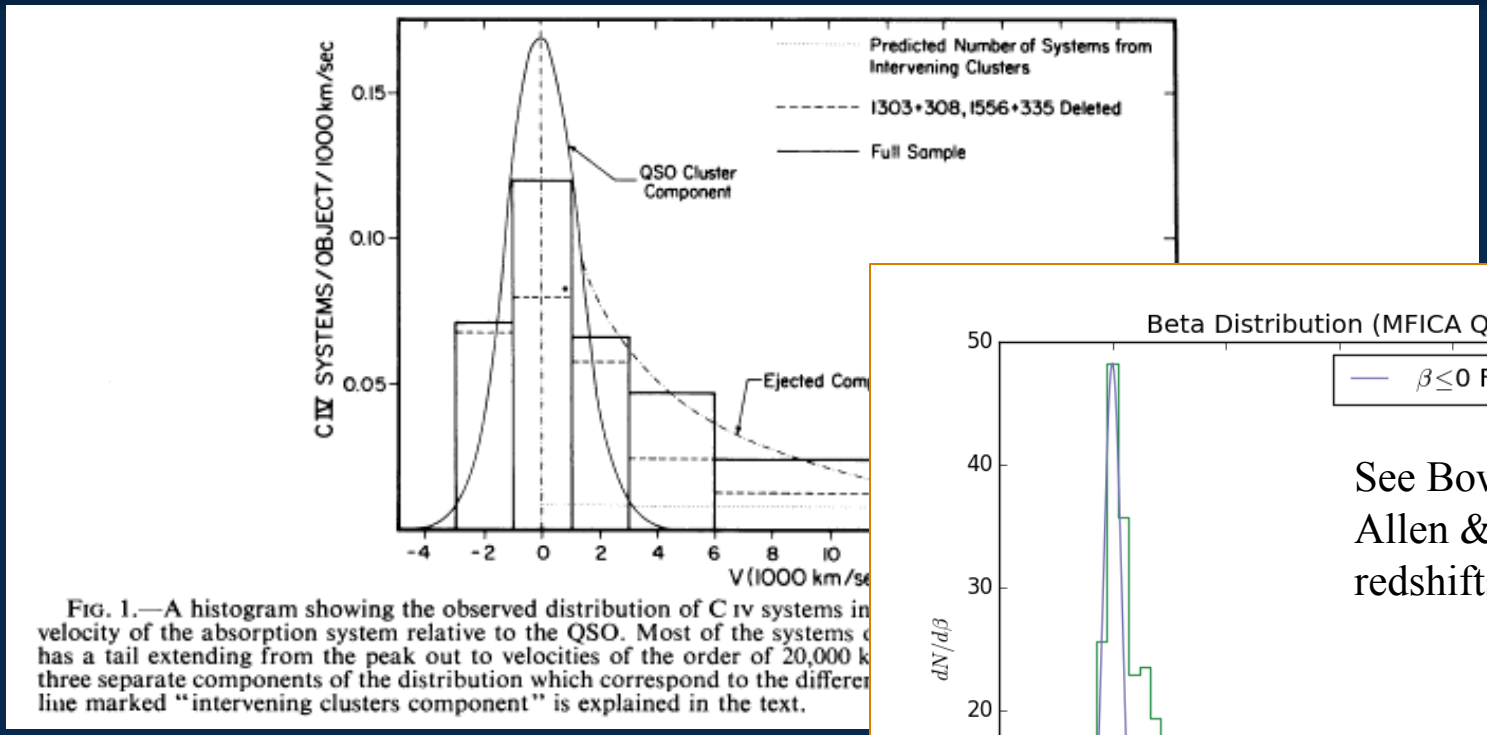
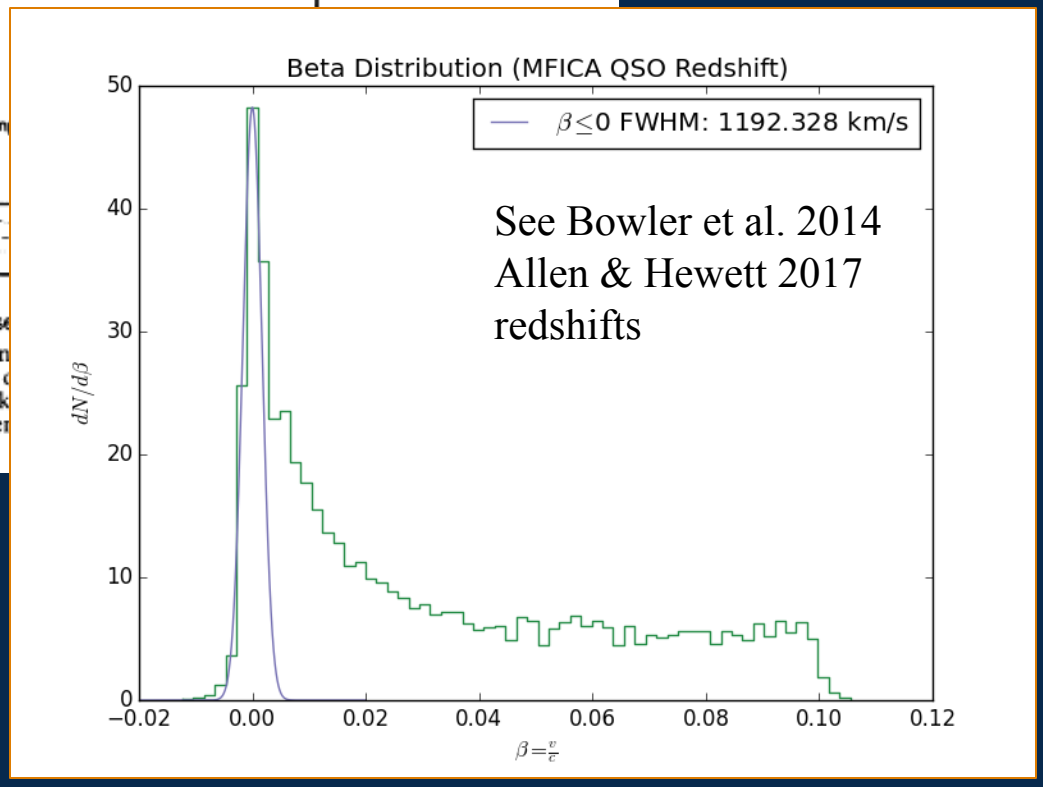


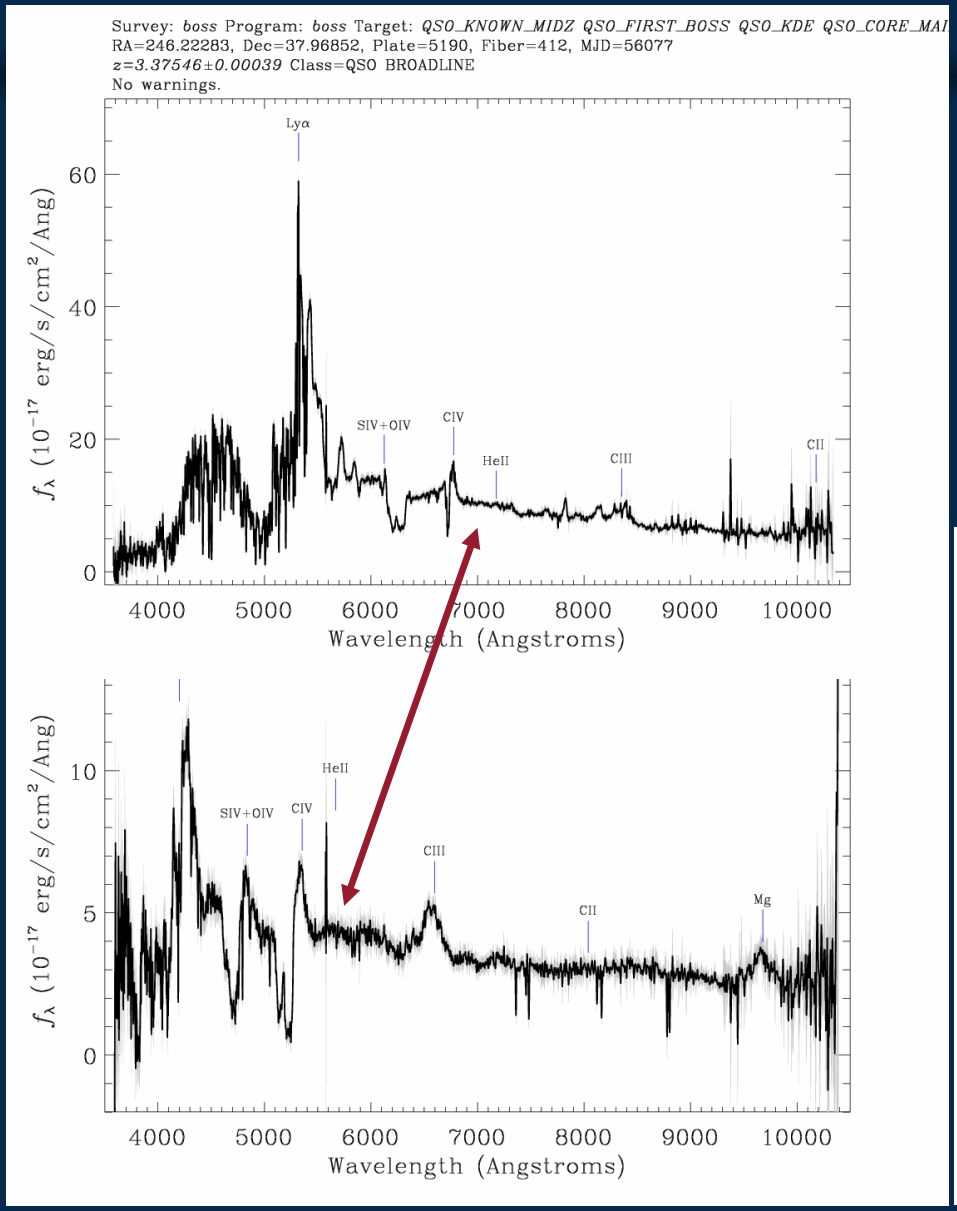
FIG. 1.—A histogram showing the observed distribution of C IV systems in velocity of the absorption system relative to the QSO. Most of the systems has a tail extending from the peak out to velocities of the order of 20,000 k three separate components of the distribution which correspond to the differe line marked "intervening clusters component" is explained in the text.

Weymann et al. 1979



Better redshifts and line-locking indicate outflows.

BALs or "BALs"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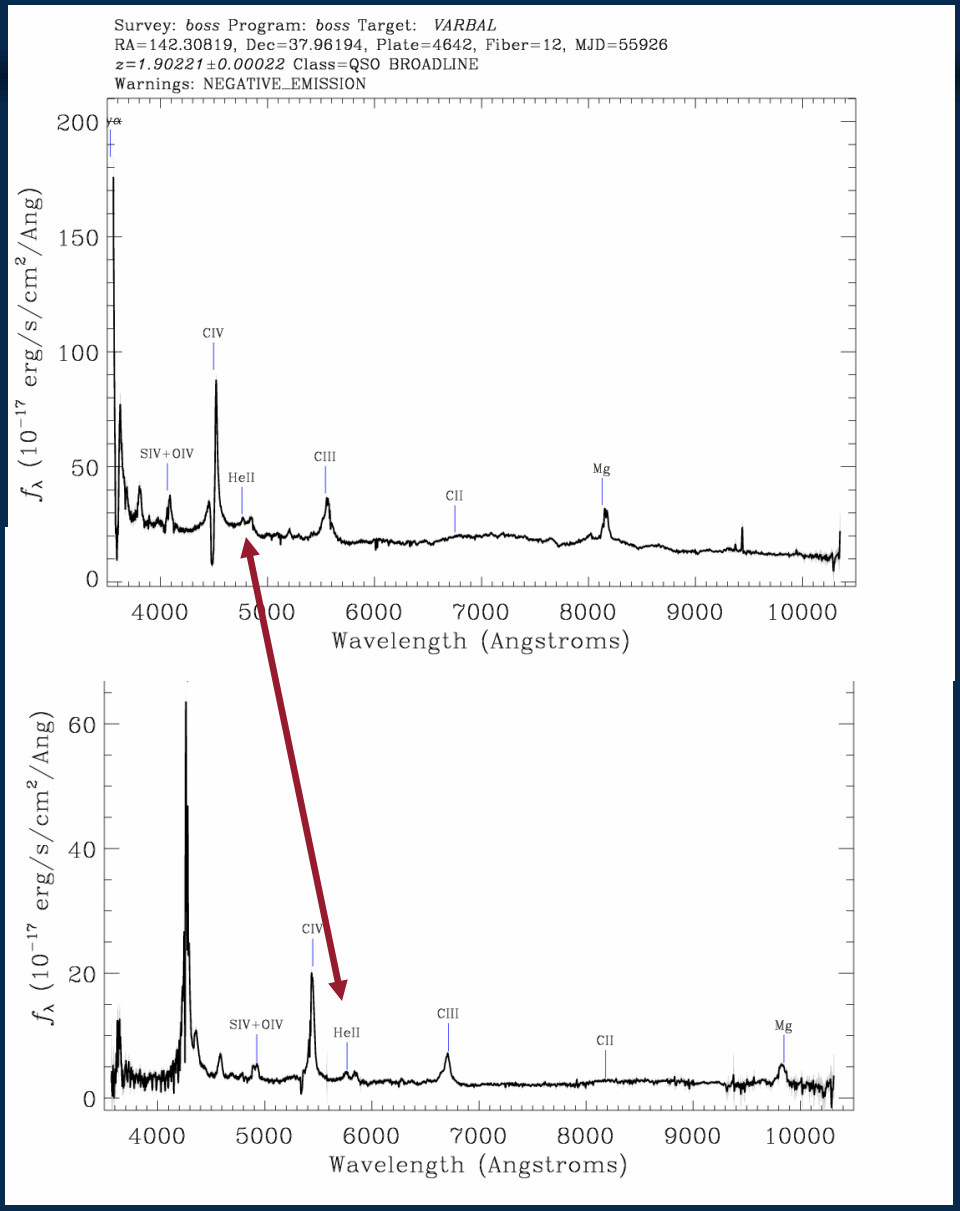
z=3.37546±0.00039 Class=QSO BROADLINE
No warnings.
Lyα
SiIV+OIV
CIV
HeII
CIII
CII
Mg
f_λ (10^{-17} erg/s/cm^2/Ang)
Wavelength (Angstroms)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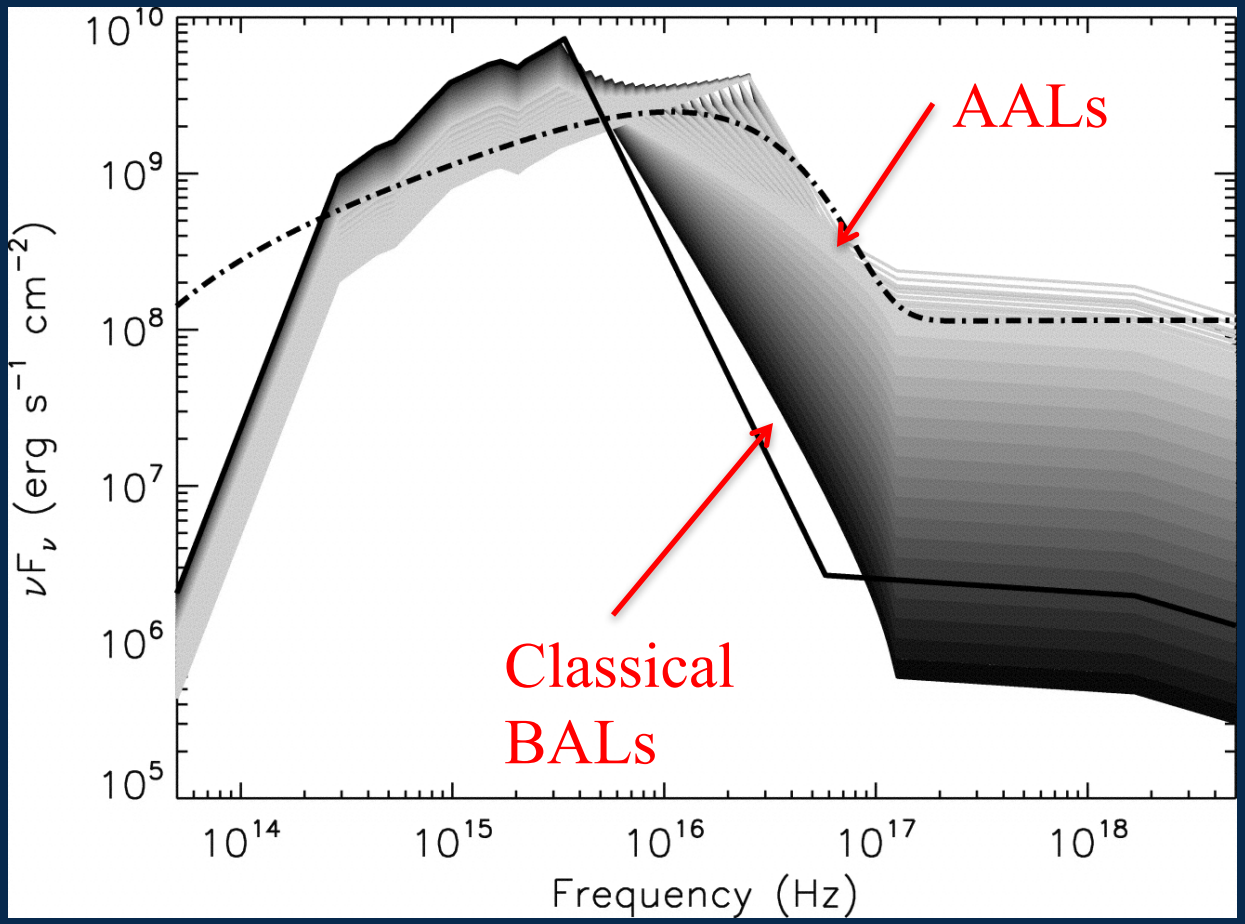
Warnings: NEGATIVE_EMISSION
Lyα
SiIV+OIV
CIV
HeII
CIII
CII
Mg
f_λ (10^{-17} erg/s/cm^2/Ang)
Wavelength (Angstroms)

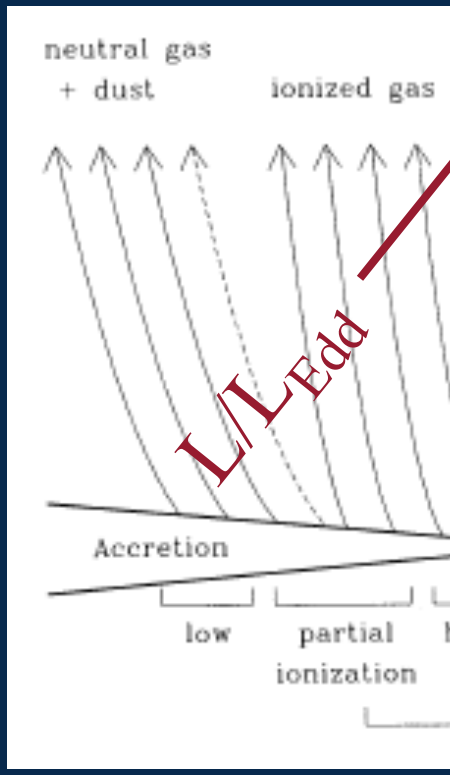
A Range of Intrinsic SEDs

Emission line differences reflect changes in the underlying SED.

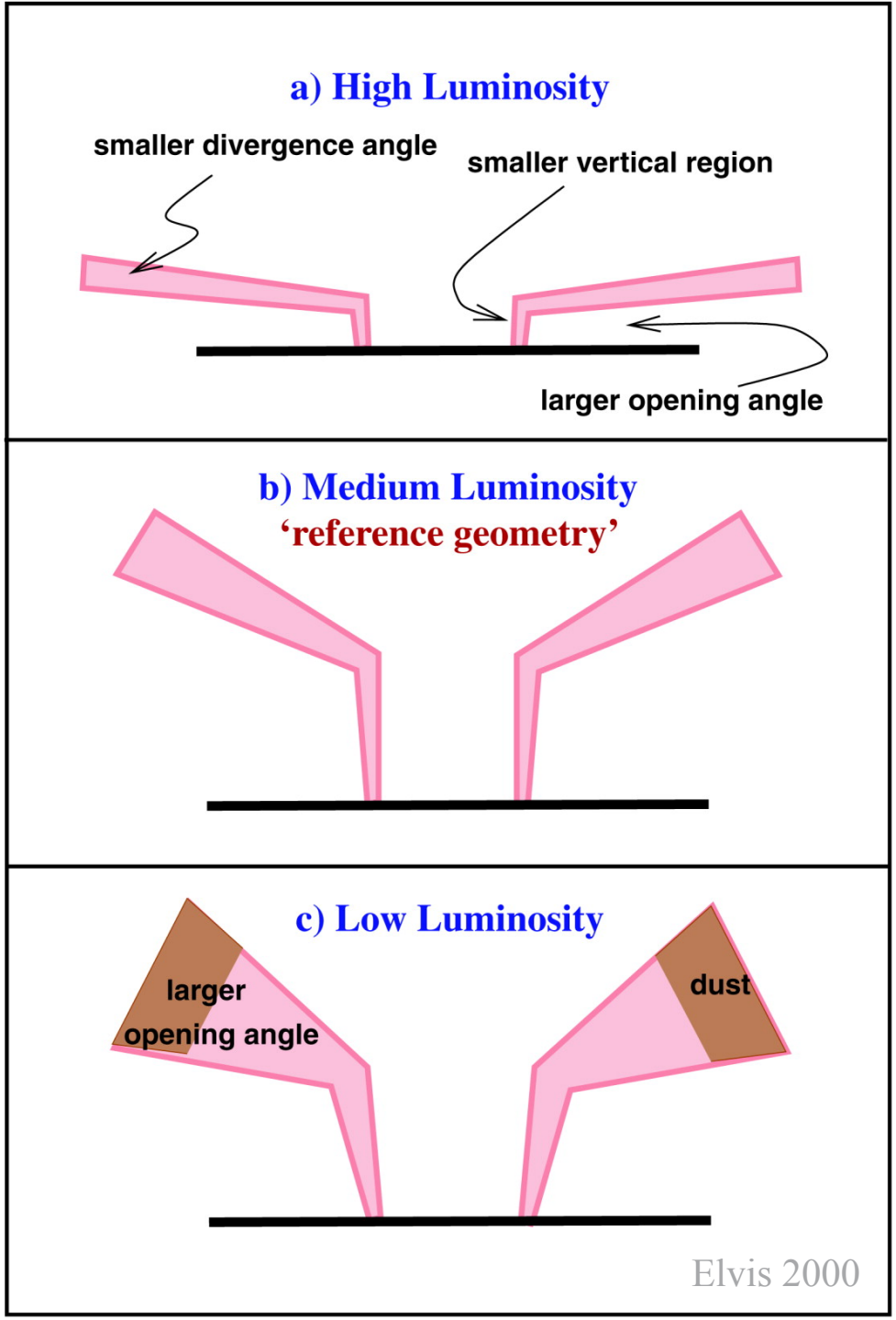
Mostly in the "unseen" EUV.



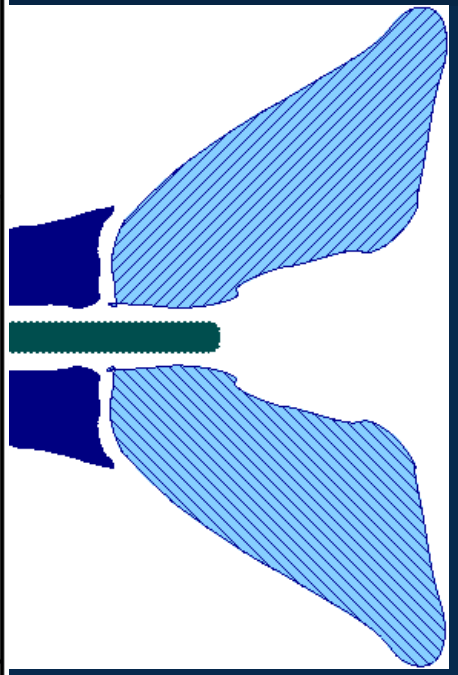
Leighly et al. 2007



Konigl & Kartje 1994



Elvis 2000



Sarah Gallagher

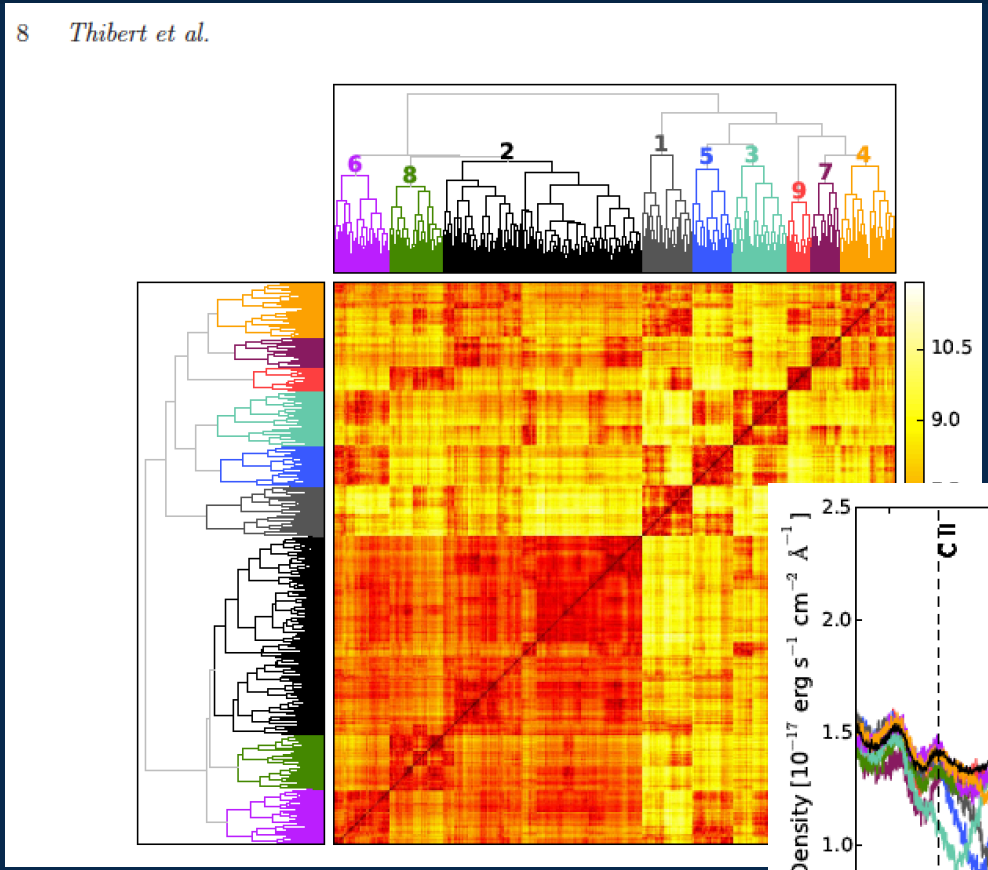
Overly Rigid Toy Models?

"Three models have been proposed to explain the presence of BALs: … orientation … bipolar wind … evolution." (Bruni+12)

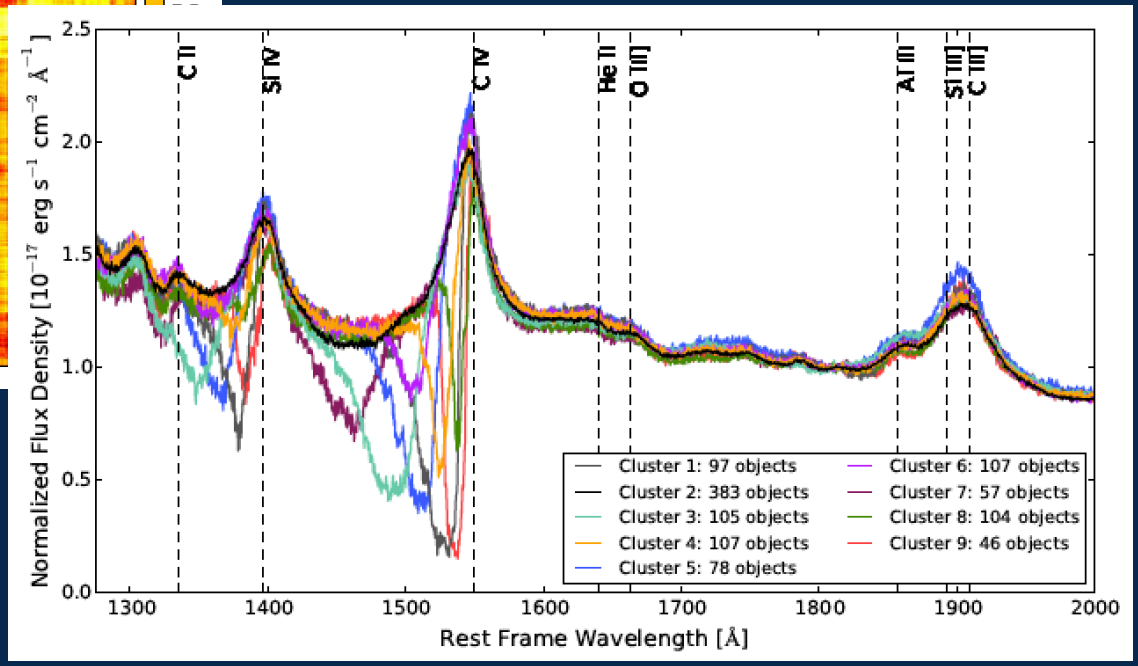
It makes no sense to me for us to talk about the problem that way. Clearly a bipolar wind model will be subject to both orientation and evolutionary effects.

Important to distinguish different sorts of outflows to understand physics (and avoid making blanket conclusions from "BALs").

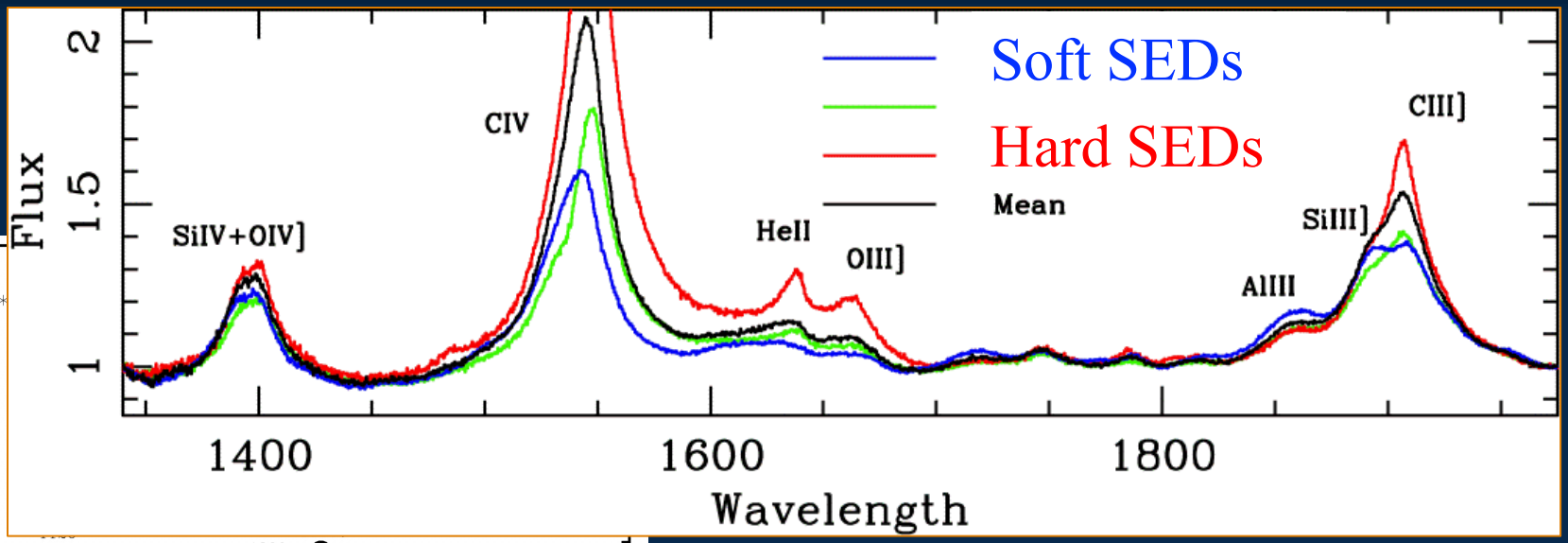
BAL Sub-Classification



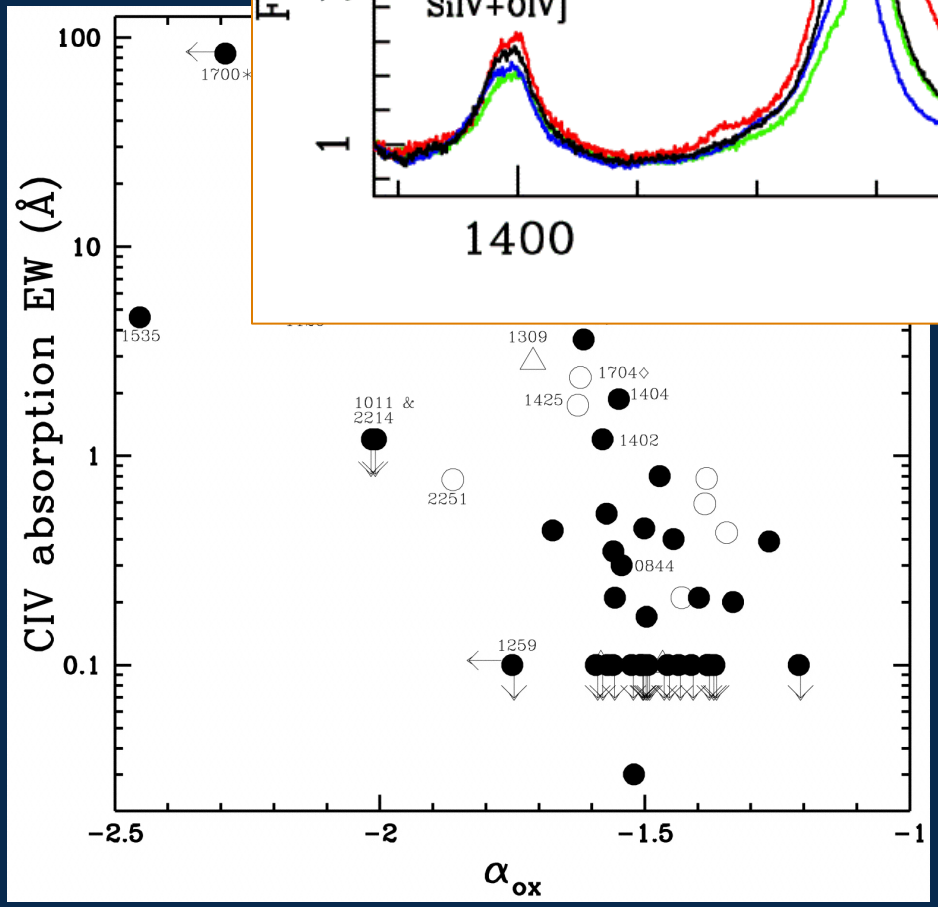
Thibert, Gallagher et al. 2017
Using machine learning (dendrograms) to classify BAL troughs



Winds in Emission



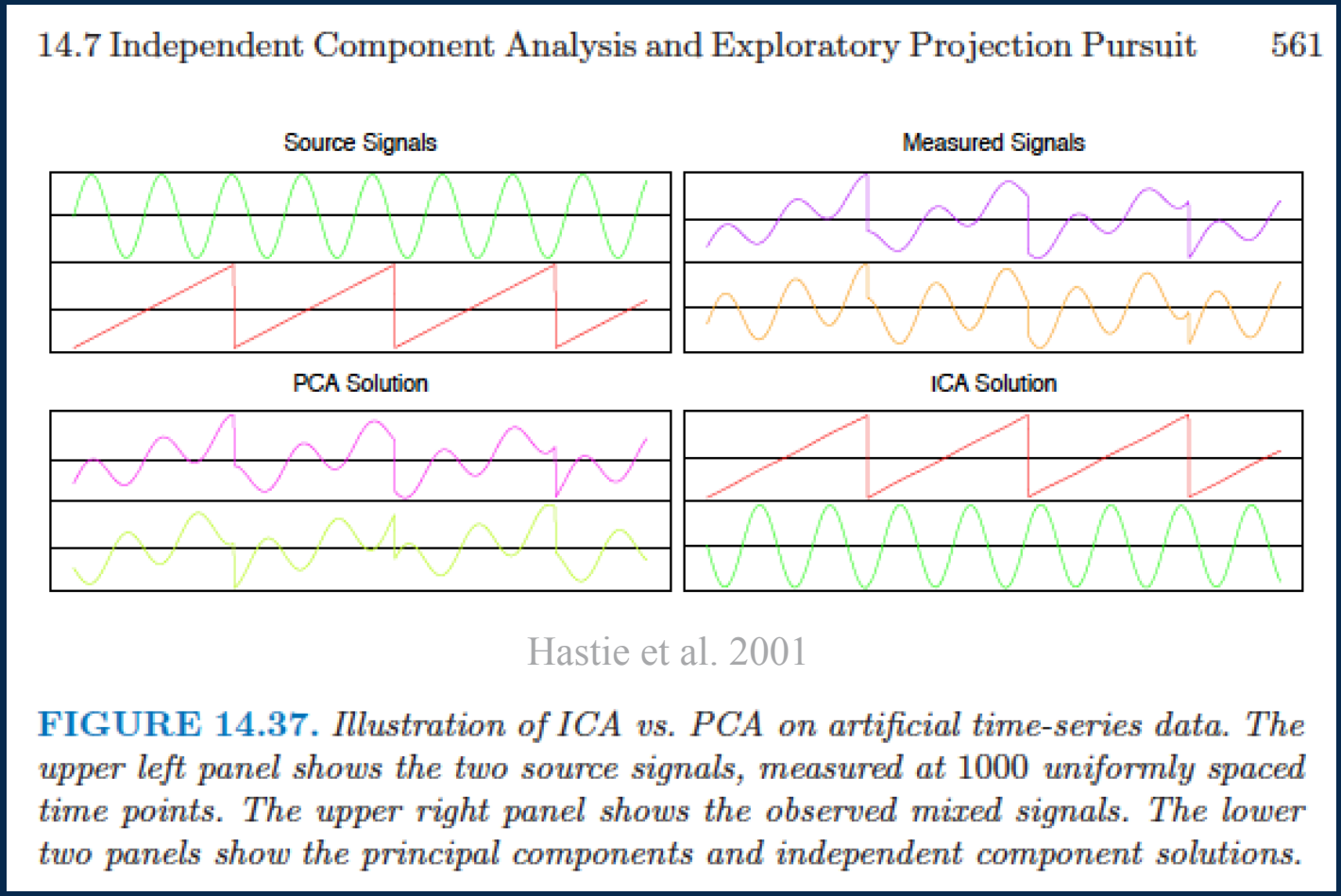
Richards et al. 2011



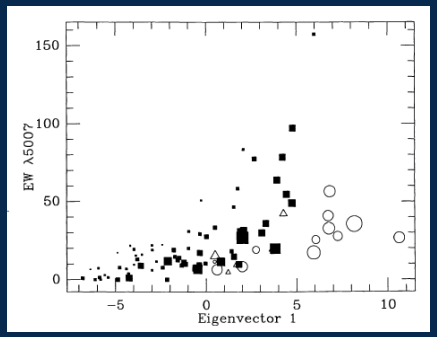
Brandt et al. 2000

Independent Component Analysis

Russian
Ambassador
US Official



Boroson & Green 1992



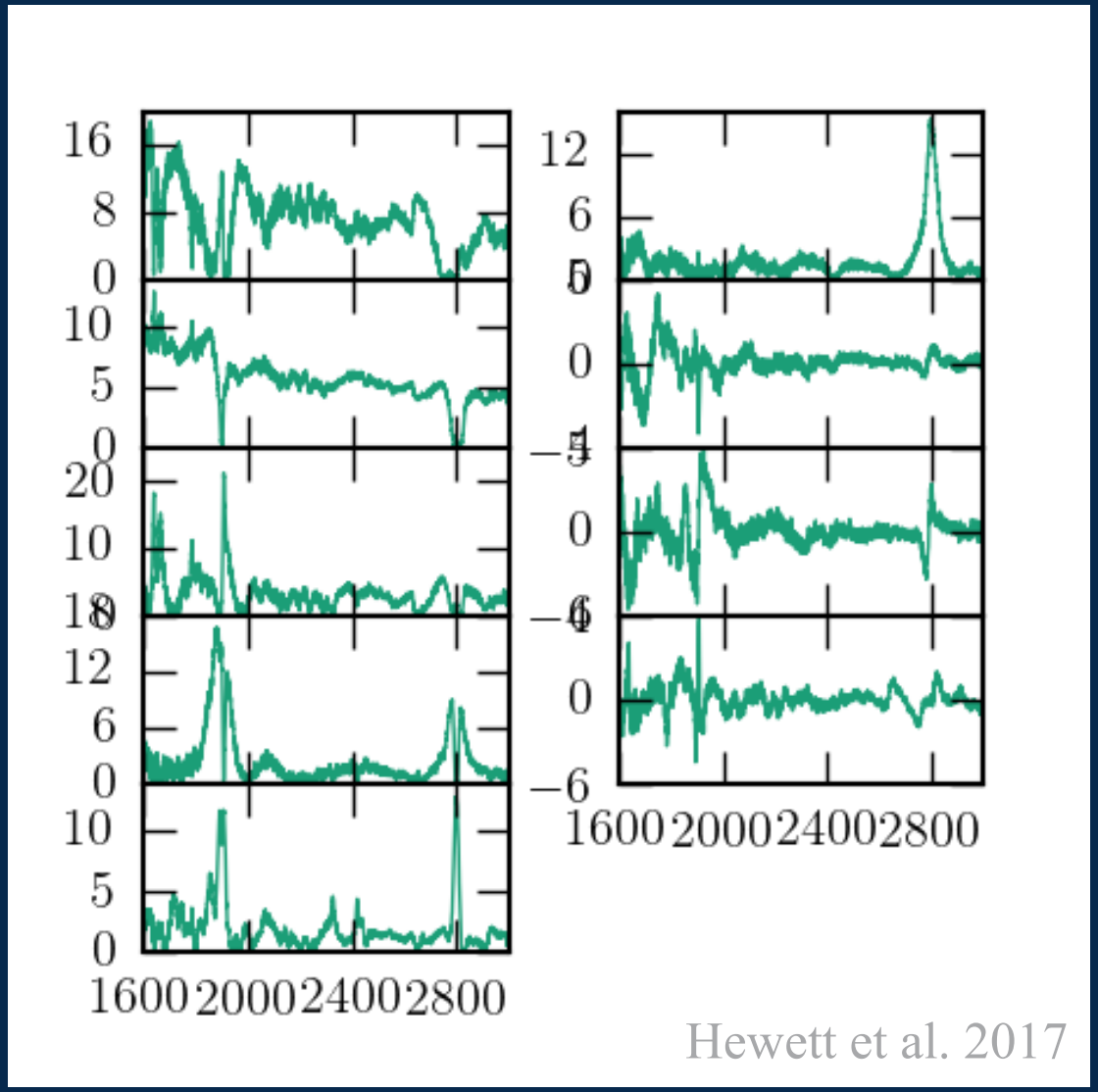
Like PCA, but much better.

Independent Component Analysis I

Quasar ICA
Longward of CIV
(excluding BALs)

6 positive definite components

3 “correction” components allowed to be negative

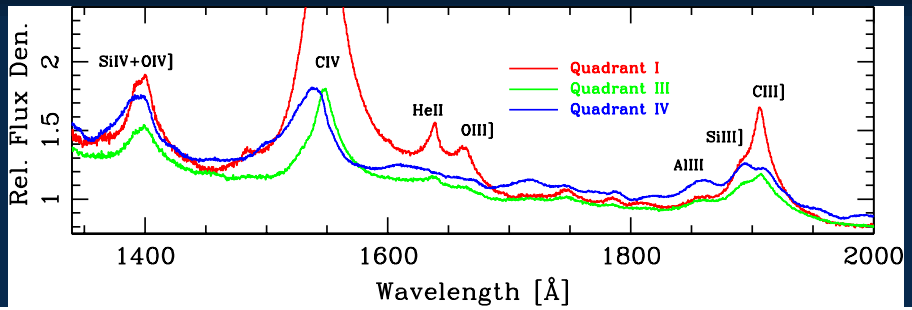


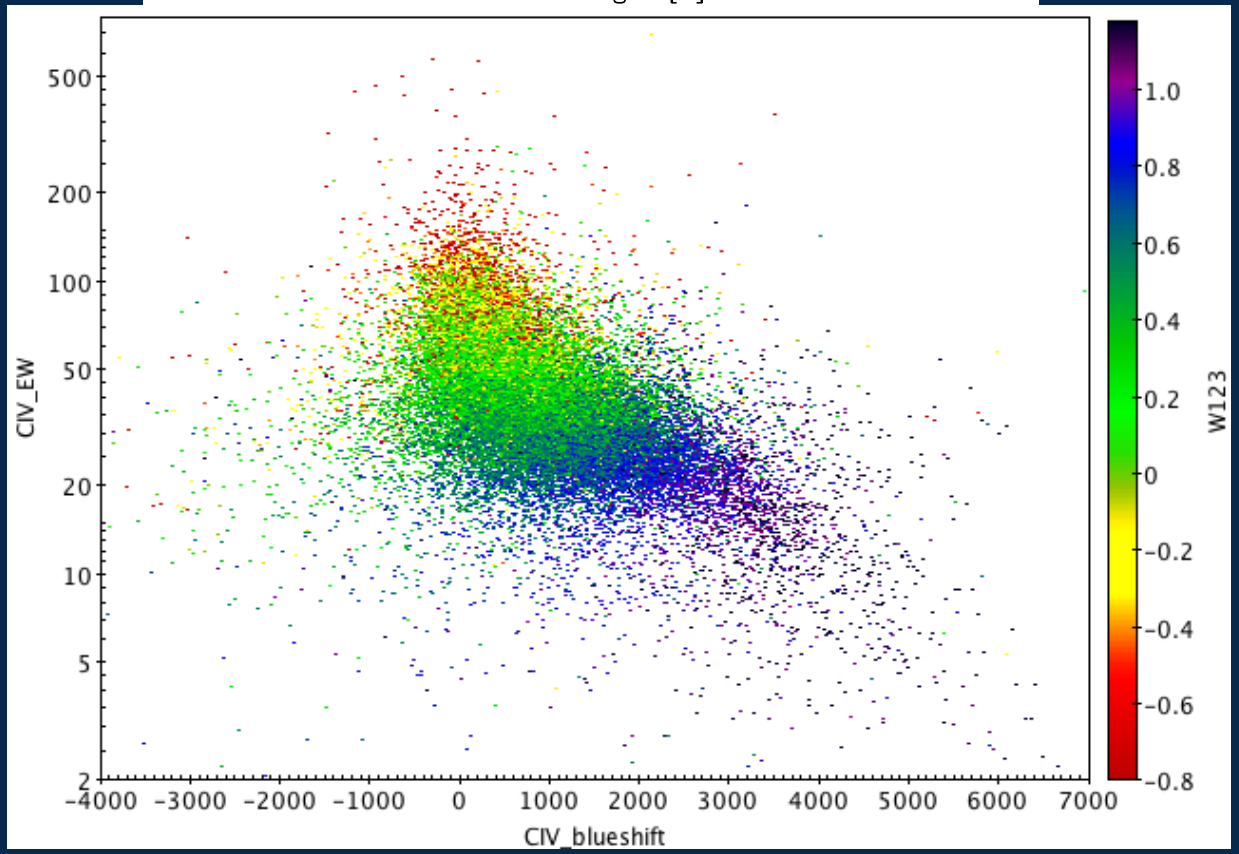
Hewett et al. 2017

Independent Component Analysis II

This is the big deal. CIII] through MgII perfectly reproduces CIV.

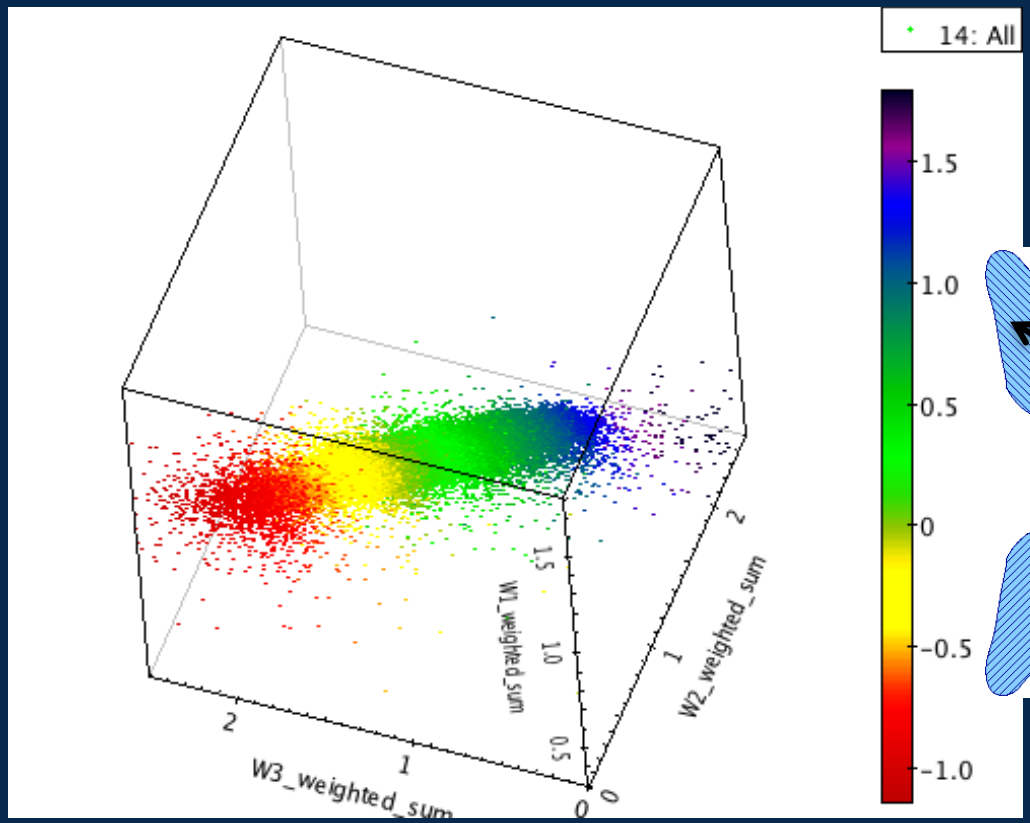
Bottom line: we can treat all the BELR lines as a whole (including low S/N).

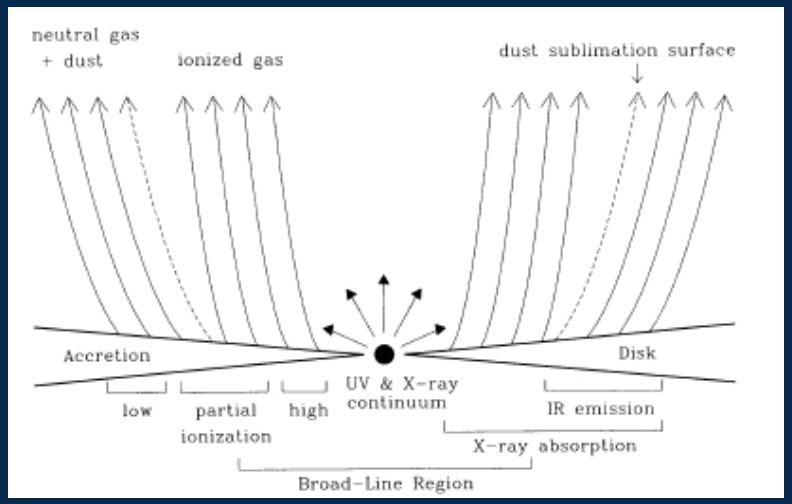


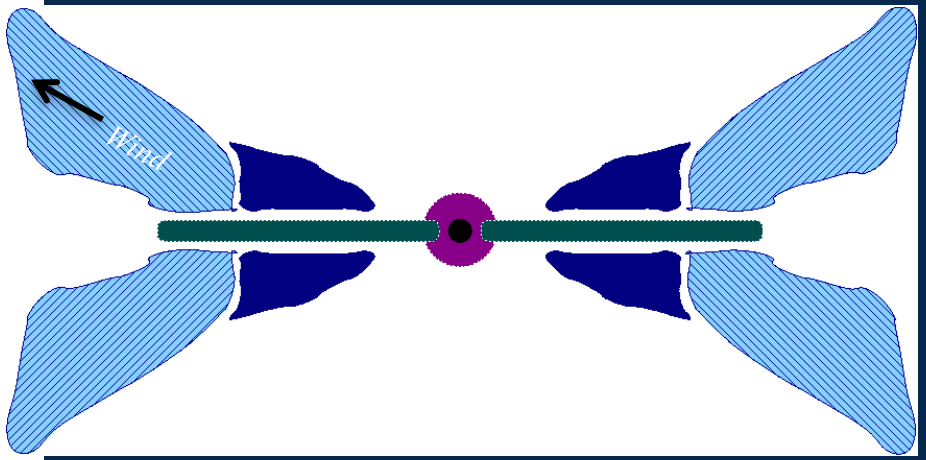


Quasars as a Continuum

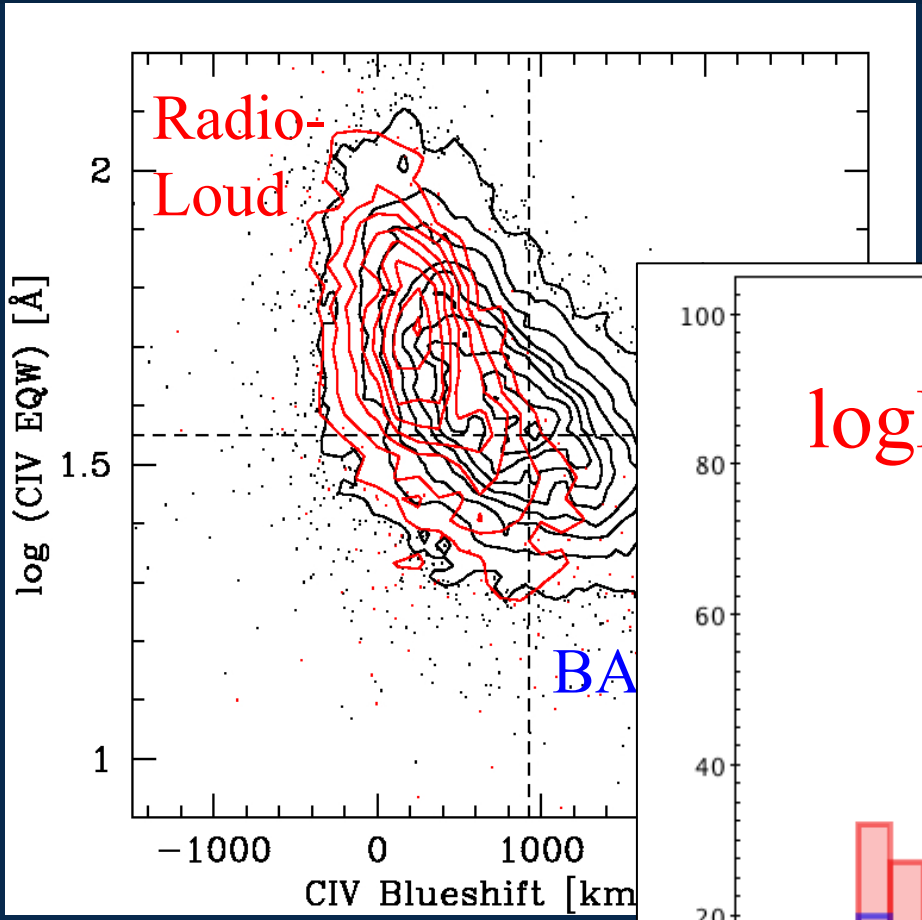
ICA Weights: a continuum distribution





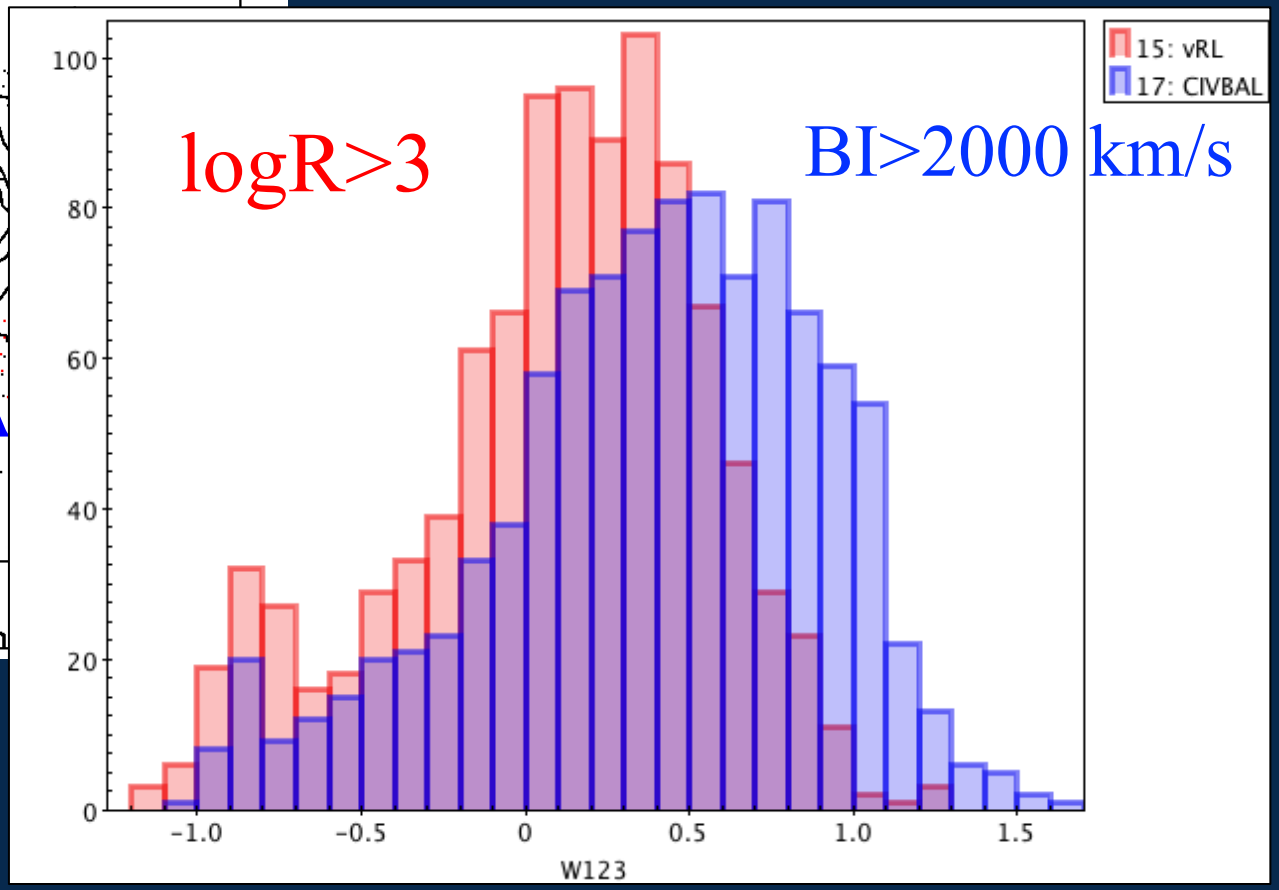


Clues from the Radio



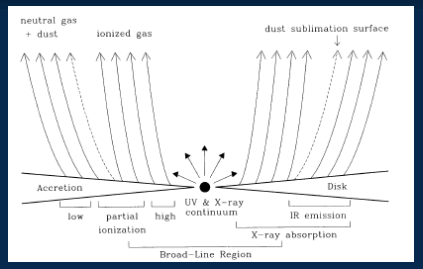
Richards et al. 2011

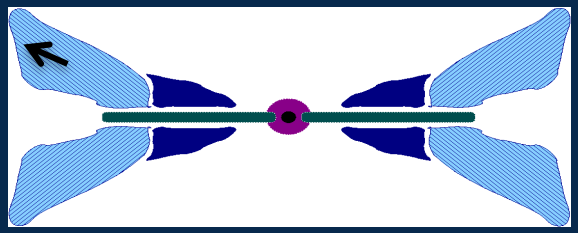
Could radio in BALs be from shocks? (Jiang et al. 2010, Zakamska et al. 2014, Stocke 1992)

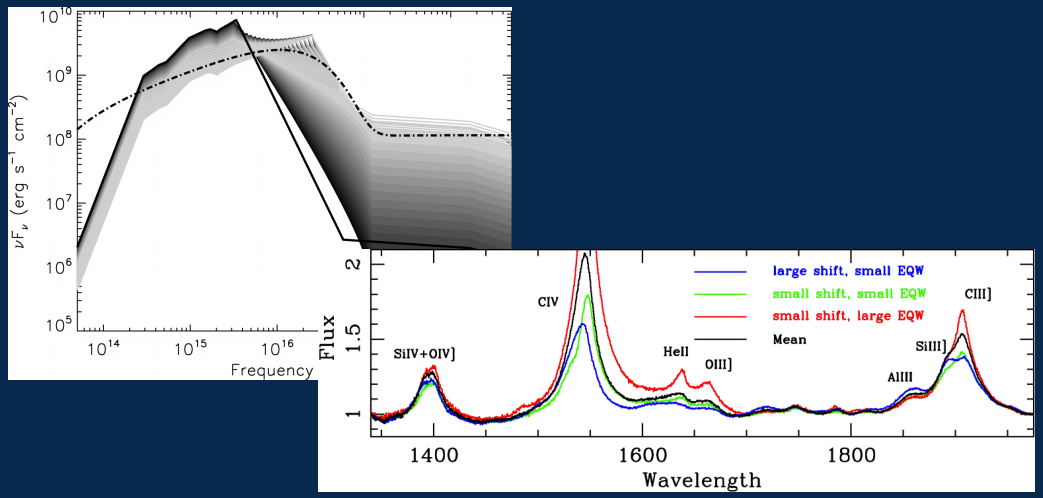


Conclusions

Quasars Are Not Uniform
(so we shouldn't expect their outflows to be uniform)

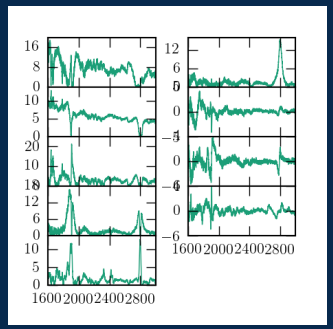


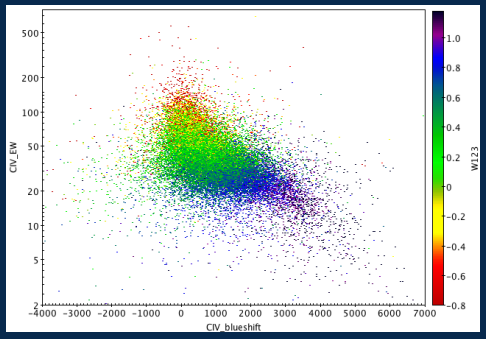




Even when we can't derive M, Mdot, we can determine location in SED distribution.

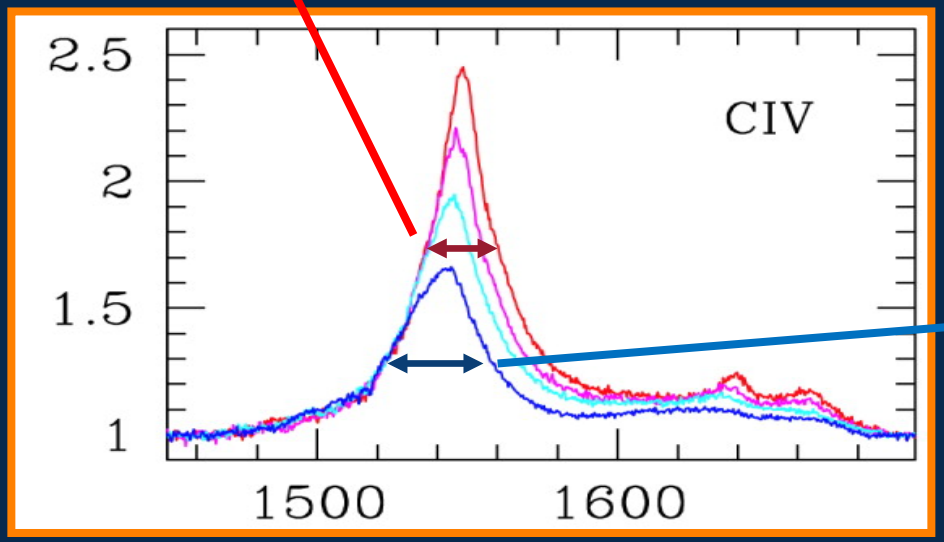
New techniques hold great promise for helping to derive physics of quasar winds.

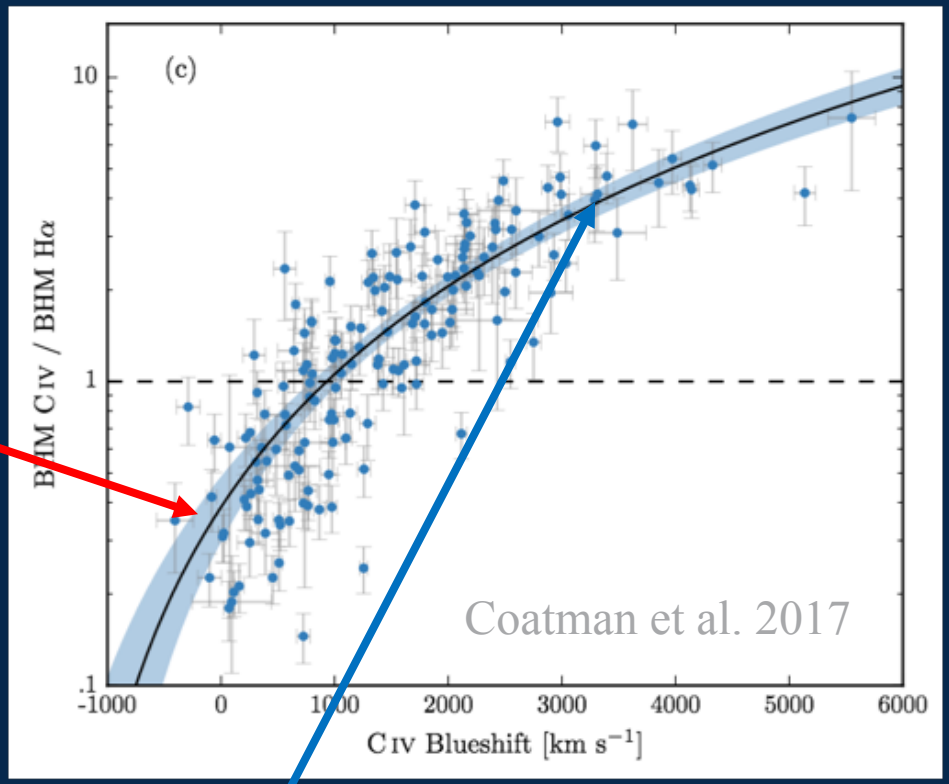




CIV BH Masses are *Inverted*

Naïve FWHM says BH mass is low, but the correction says it is high.





Naïve FWHM says BH mass is high, but correction says it is low

Caveats

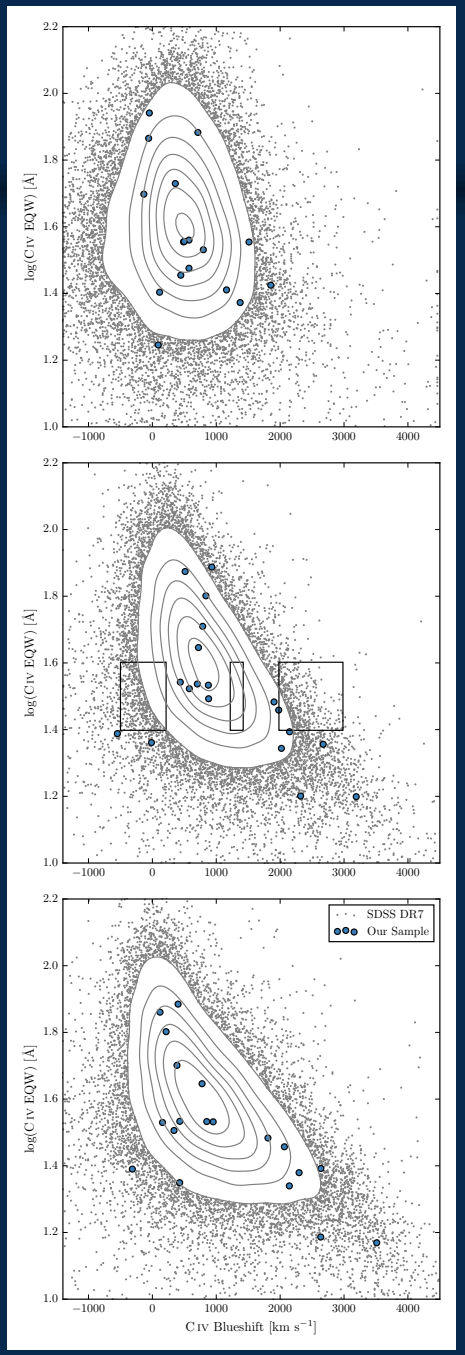
Why hasn't this been done before?

- Astronomers and statisticians speak different languages.
- But more importantly, you *have* to get the redshifts right *first*.

SDSS pipeline redshifts

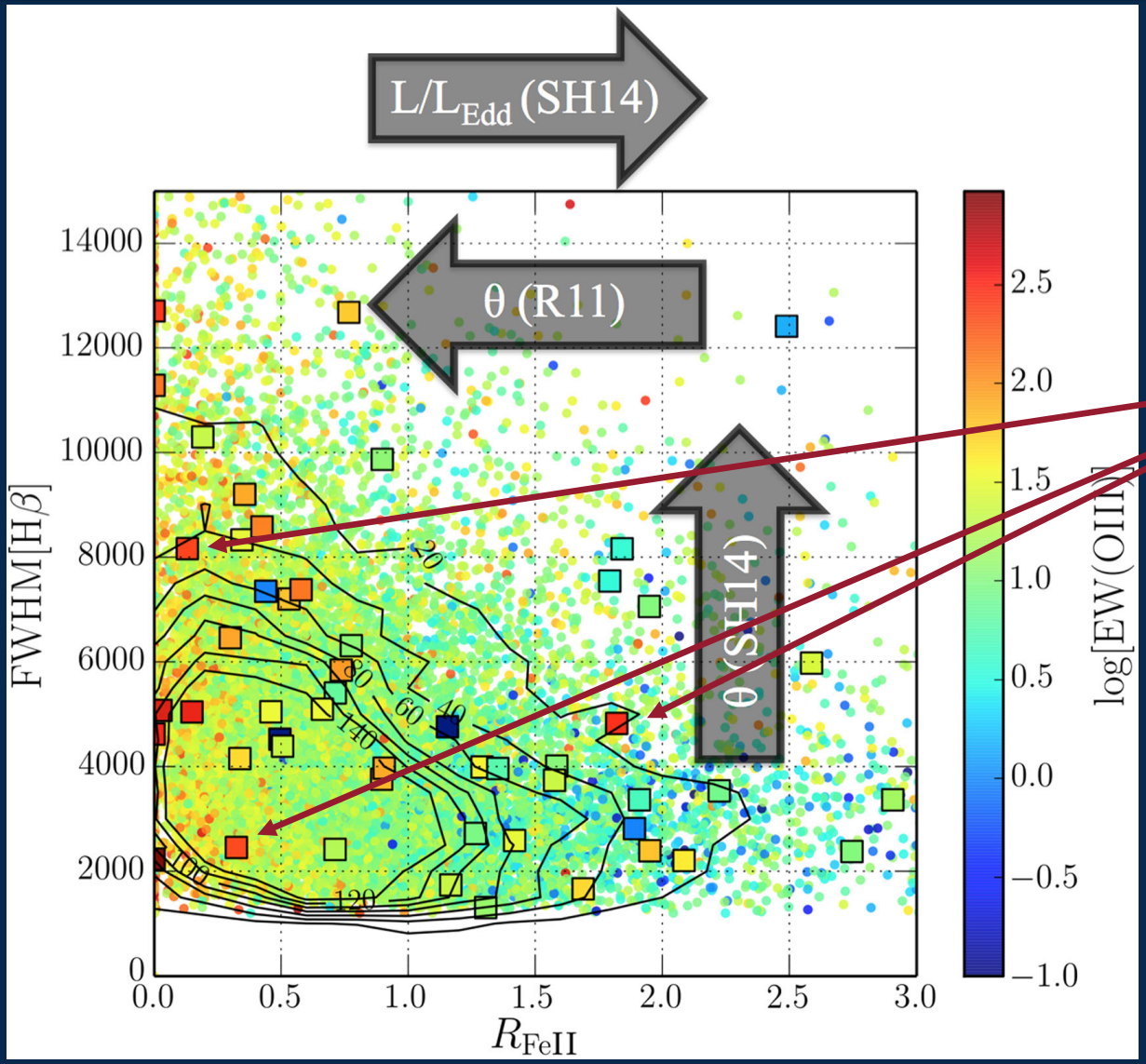
HW10 redshifts

Allen & Hewett 2017 redshifts



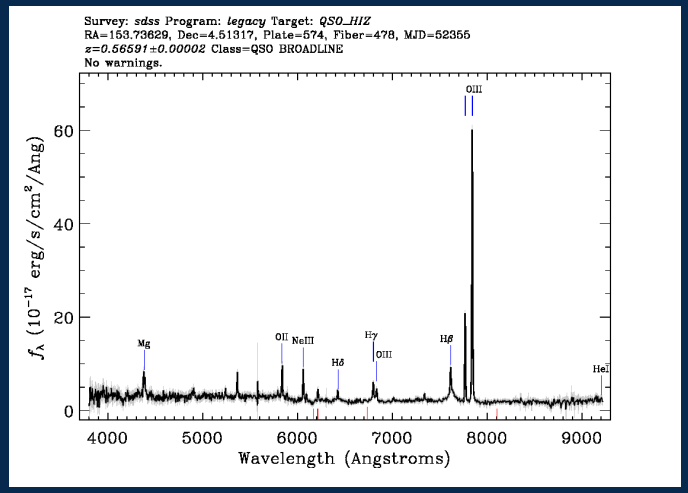
Coatman et al. 2016

"LoBALs" in EV1



LoBALs don't have strong [OIII]. What are these?

Matthews, Knigge & Long 2017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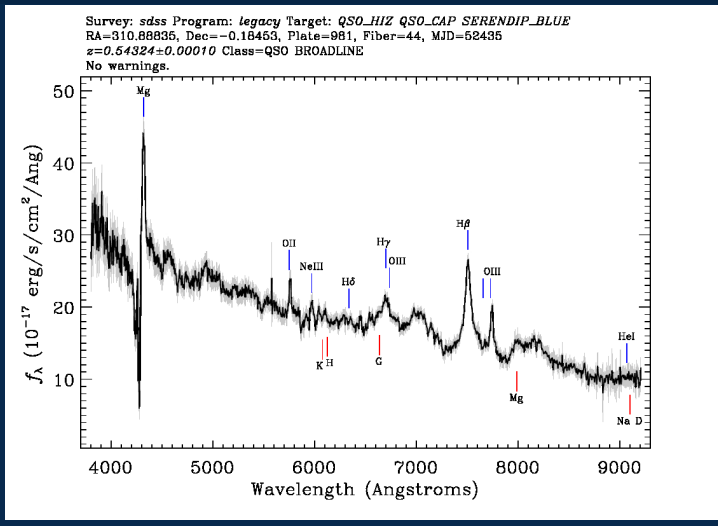
z=0.56591±0.00002 Class=QSO BROADLINE
No warnings.
Mg
OII
NeIII
Hδ
Hγ
OIII
Hβ
OIII
HeI
f_λ (10^{-17} erg/s/cm^2/Ang)
Wavelength (Angstroms)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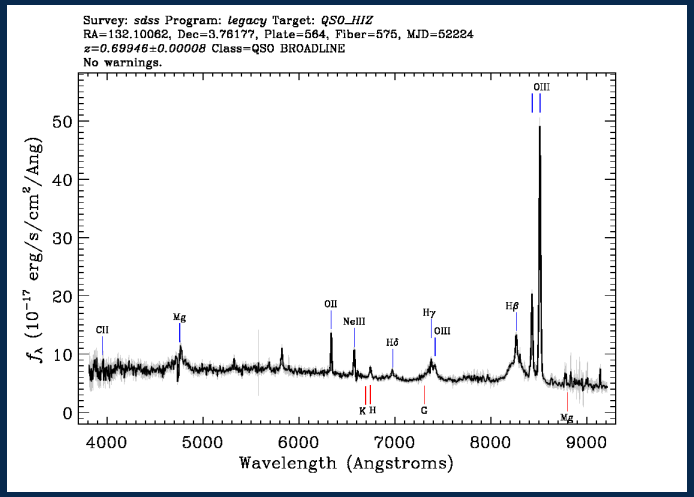
z=0.54324±0.00010 Class=QSO BROADLINE
No warnings.
Mg
OII
NeIII
Hδ
Hγ
OIII
Hβ
OIII
HeI
K
H
G
Mg
Na D
f_λ (10^{-17} erg/s/cm^2/Ang)
Wavelength (Angstroms)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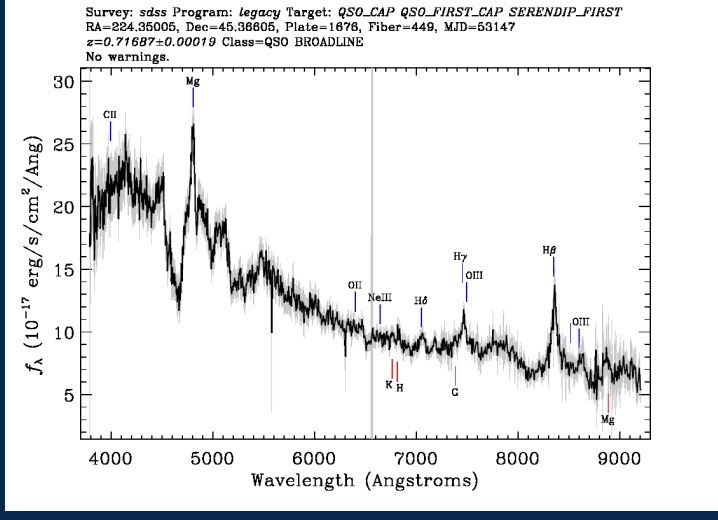
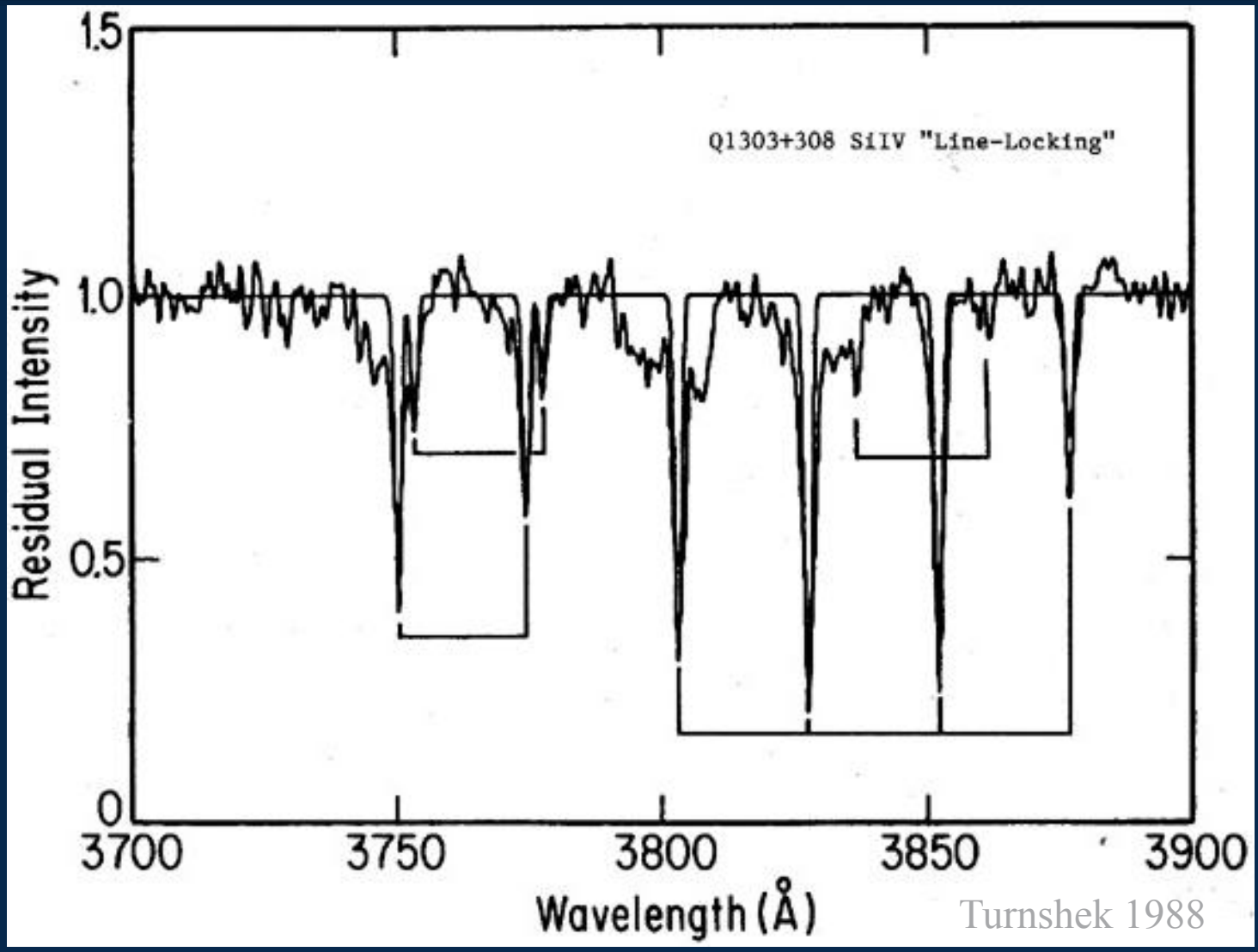
RA=132.10062, Dec=3.76177, Plate=564, Fiber=575, MJD=52224
z=0.69946±0.00008 Class=QSO BROADLINE
No warnings.
CII
Mg
OII
NeIII
Hδ
Hγ
OIII
Hβ
OIII
K
H
G
Mg
f_λ (10^{-17} erg/s/cm^2/Ang)
Wavelength (Angstroms)


Survey: sdss Program: legacy Target: QSO_CAP QSO_FIRST_CAP SERENDIP_FIRST
RA=224.35005, Dec=45.36605, Plate=1676, Fiber=449, MJD=53147
z=0.71687±0.00019 Class=QSO BROADLINE
No warnings.
CII
Mg
OII
NeIII
Hδ
Hγ
OIII
Hβ
OIII
K
H
G
Mg
f_λ (10^{-17} erg/s/cm^2/Ang)
Wavelength (Angstroms)

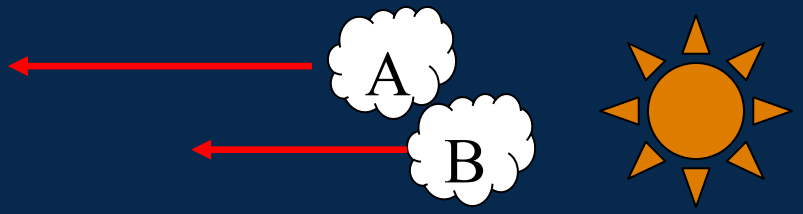
Line Locking Then

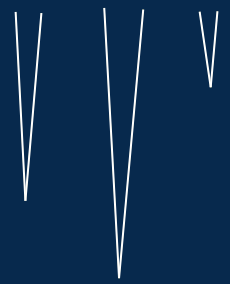


Turnshek 1988

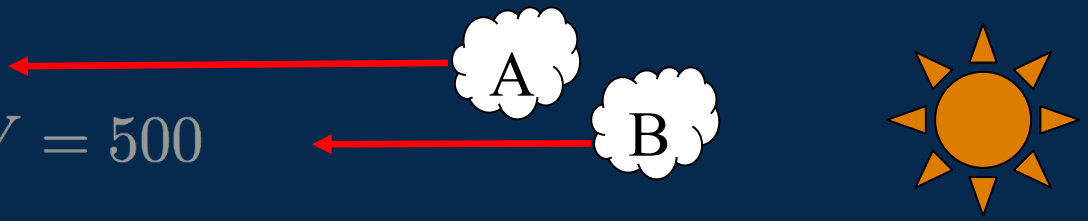
Line Locking How To

$V_B < V_A; \Delta V < 500$



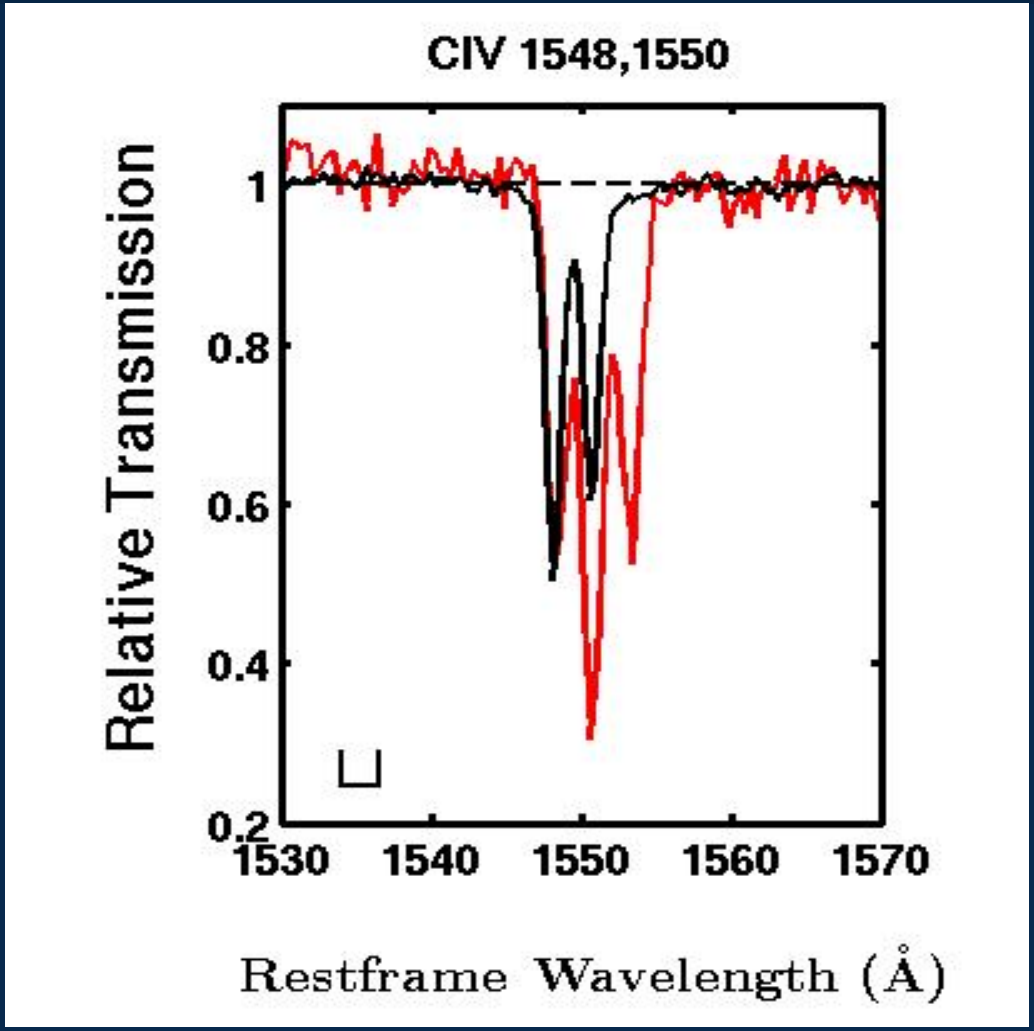


$V_B < V_A; \Delta V = 500$



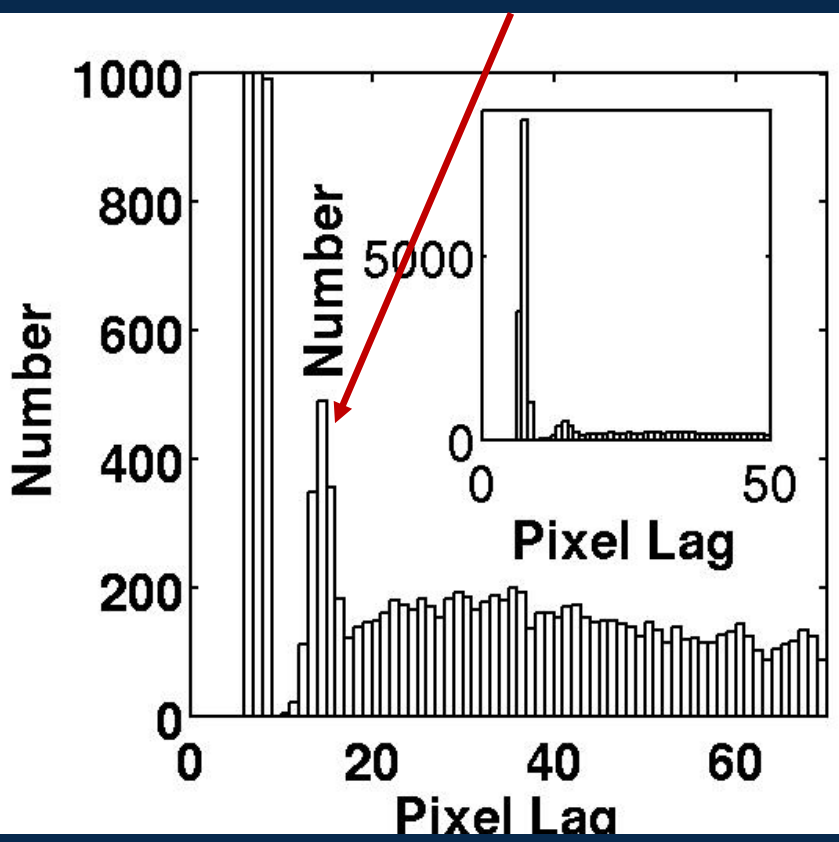
Acceleration of cloud A drops due to 1550 absorption by cloud B at 1548; relative velocity locked at 500 km/s.

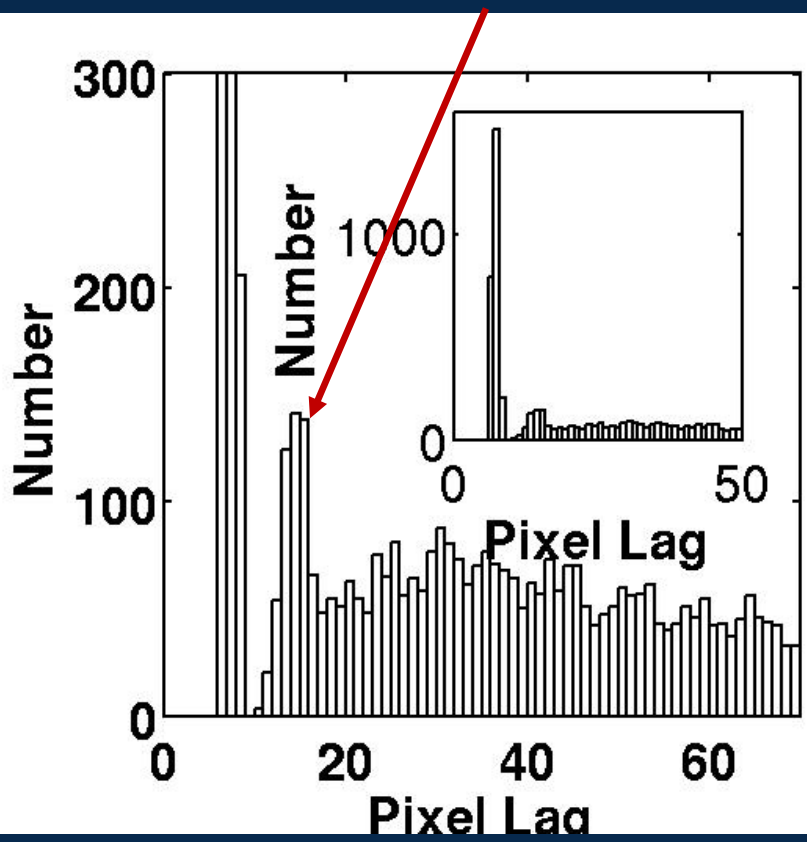
Line Locking Now



Bowler+14

Line Locking Now



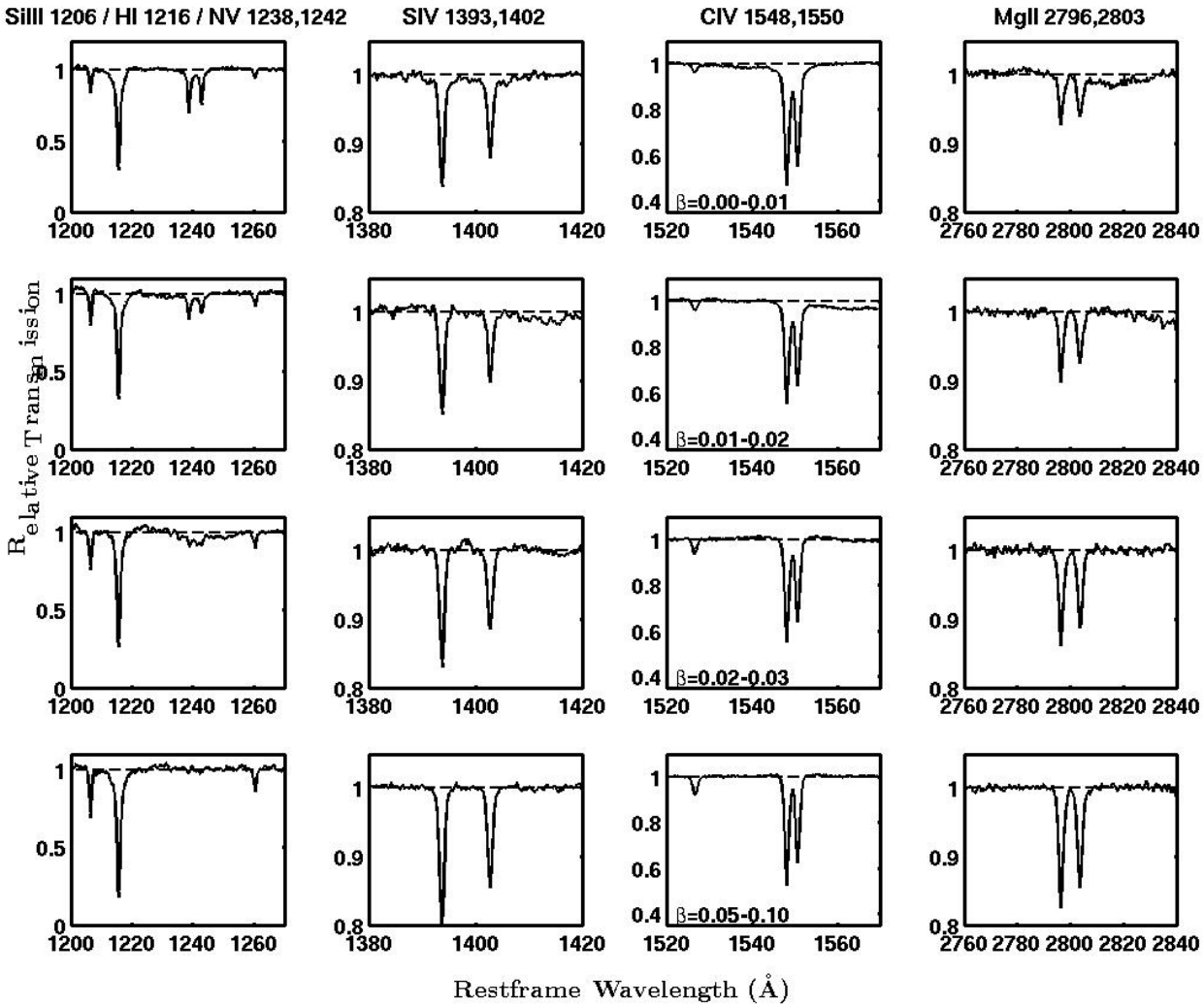


nonBALs

BALs

Bowler+14

Ionization with Velocity



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