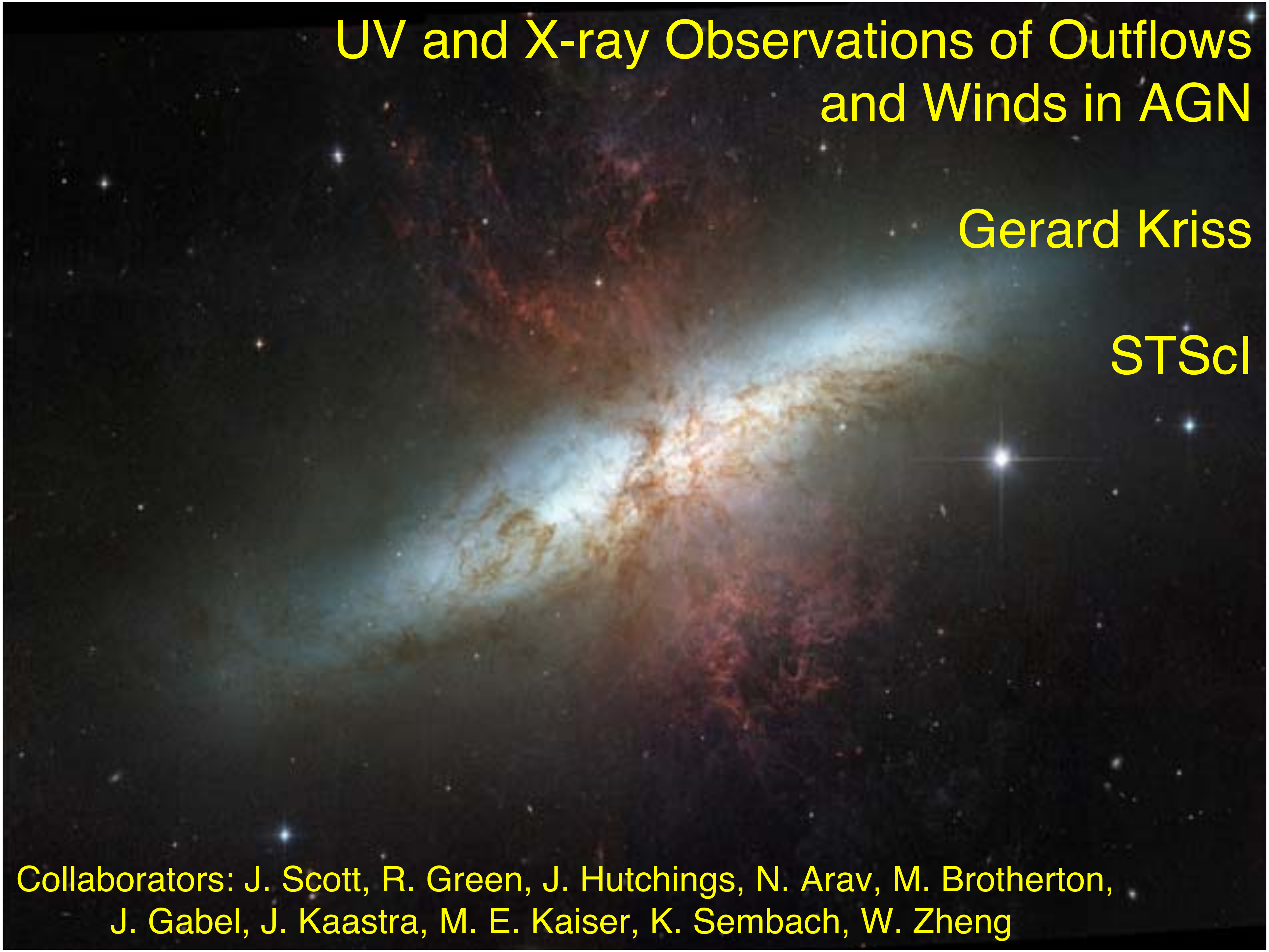
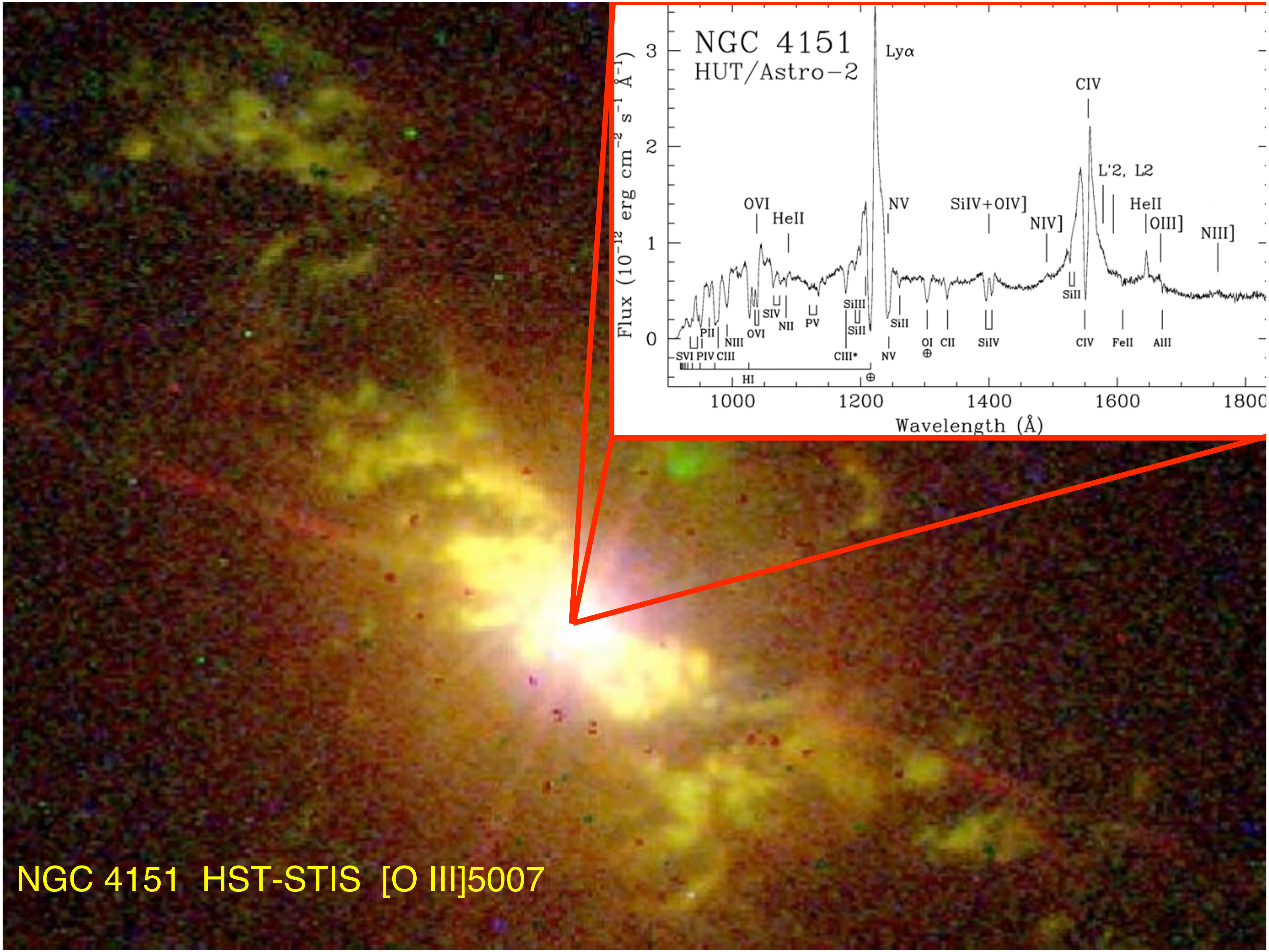


UV and X-ray Observations of Outflows and Winds in AGN

Gerard Kriss

STScI

Collaborators: J. Scott, R. Green, J. Hutchings, N. Arav, M. Brotherton, J. Gabel, J. Kaastra, M. E. Kaiser, K. Sembach, W. Zheng


NGC 4151
HUT/Astro-2
Lyα
CIV
L'2, L2
OVI
HeII
NV
SiIV+OIV]
NIV]
HeII
OIII]
NIII]
Flux (10^-12 erg cm^-2 s^-1 Å^-1)
Wavelength (Å)
1000
1200
1400
1600
1800
NGC 4151 HST-STIS [O III]5007

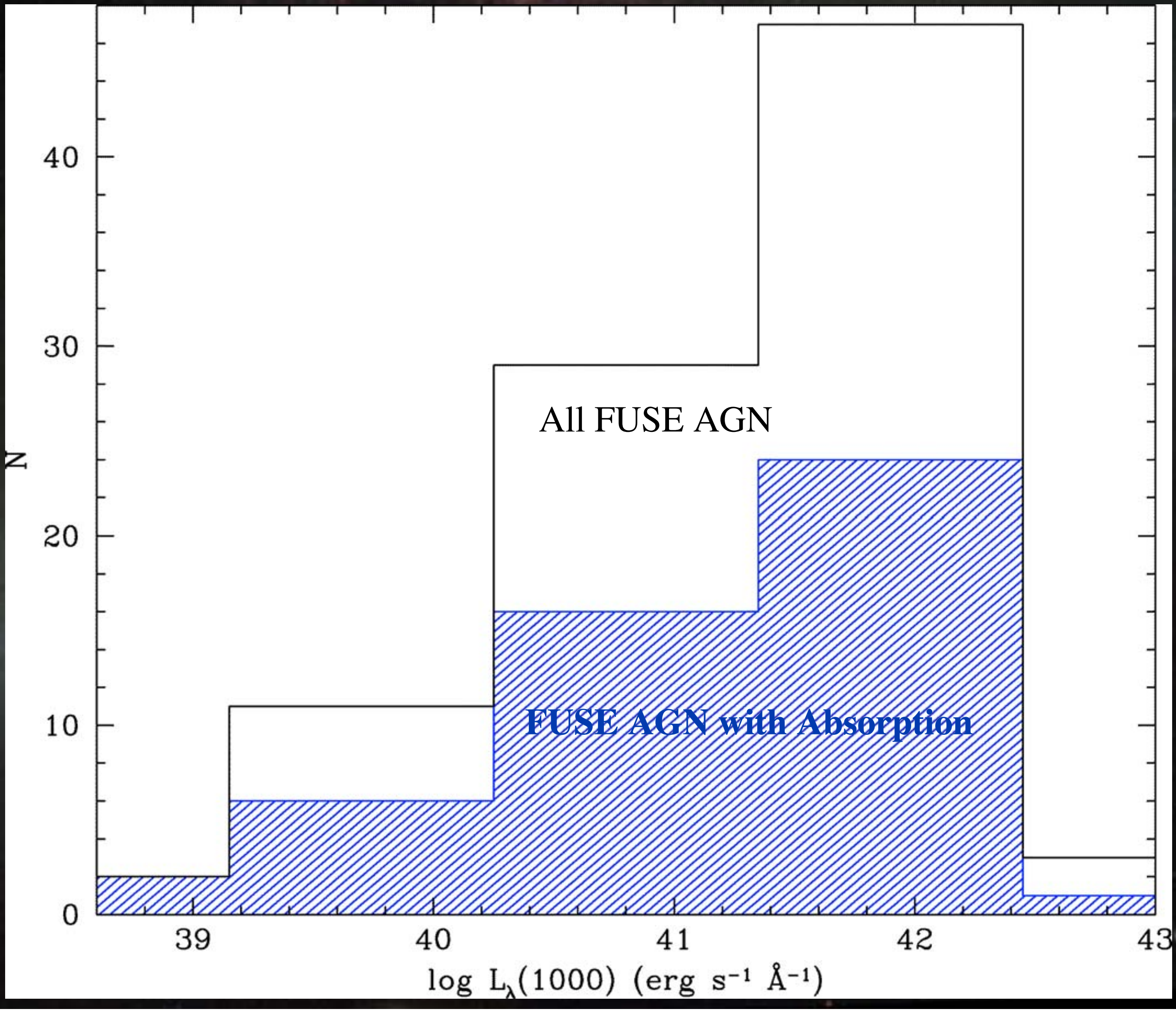
The Influence of AGN Outflows

- ★ **They may affect dispersal of heavy elements into the IGM and ICM.** [Cavaliere et al. 2002; Adelberger et al. 2003; Granato et al. 2004; Scannapieco & Oh 2004]
- ★ **They influence the ionization structure of the IGM.** [Kriss et al. 1997].
- ★ **They are intertwined with the evolution of the host galaxy.** [Silk & Rees 1998; Wyithe & Loeb 2003].
- ★ **We still aren't sure how the outflows are created, what structure they have, or how much mass and energy they carry.**
  - A key question: do the outflows escape the confines of the host galaxy?
- ★ **Crucial to understanding the workings of the central engine:**
  - Accretion process
  - Total energy budget
- ★ **Low-redshift AGN are the nearest and brightest.**
  - ➢ We can study these at the highest angular scales and best S/N.

Summary of the FUSE AGN Survey Results

- ★ **103 AGN observed with FUSE with $z < 0.15$.**
  - 81 have S/N> 10 per Angstrom, adequate for absorption searches.
- ★ **In the low-z sample (for which O VI is in the FUSE bandpass):**
  - 153 spectra of 81 unique AGN
  - 73 Type 1
  - 8 Type 2
- ★ **Low-z AGN are bluer than high-z AGN: Scott et al. (2004).**
- ★ **Their spectral energy distributions are broadly consistent with accretion disk models (Shang et al. 2004).**
- ★ **Strong, broad O VI emission is visible in all Type 1 AGN.**
- ★ **27/73 of these also show strong, *narrow* O VI emission.**
- ★ **Over 50% (41/73) show intrinsic O VI absorption.**
  - (35/75 reported by Dunn et al. 2007, 2008.)
- ★ **No intrinsic Lyman limits.**
- ★ **No intrinsic H_2 absorption. ($N_{H2} < 10^{16}$ cm^{-2} in NGC 4151.)**

Absorption is Common at All Luminosities



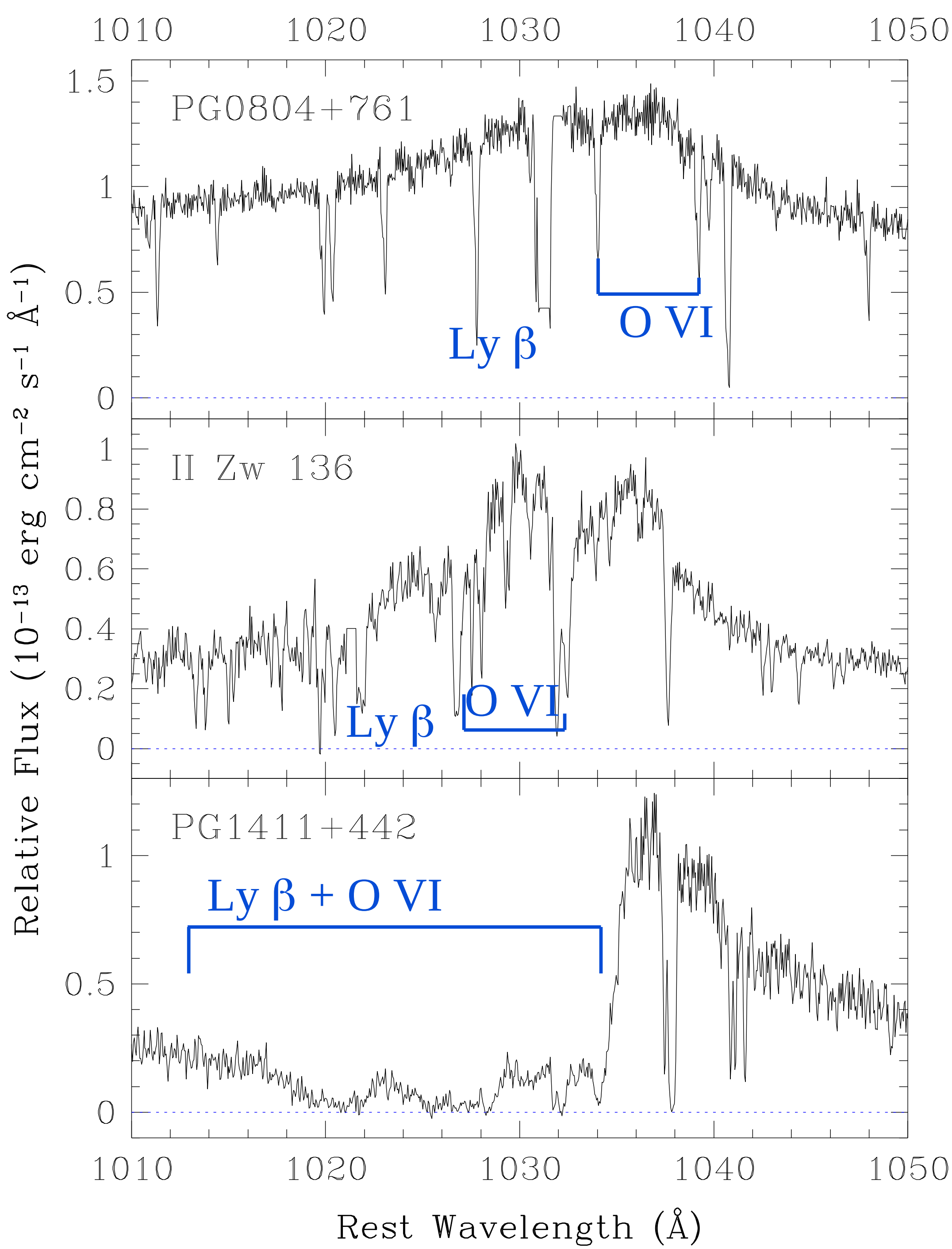
Outflow Velocity Increases with Luminosity

- Note hint of a low ΔV population at all luminosities.

O VI Absorption-Line Morphologies

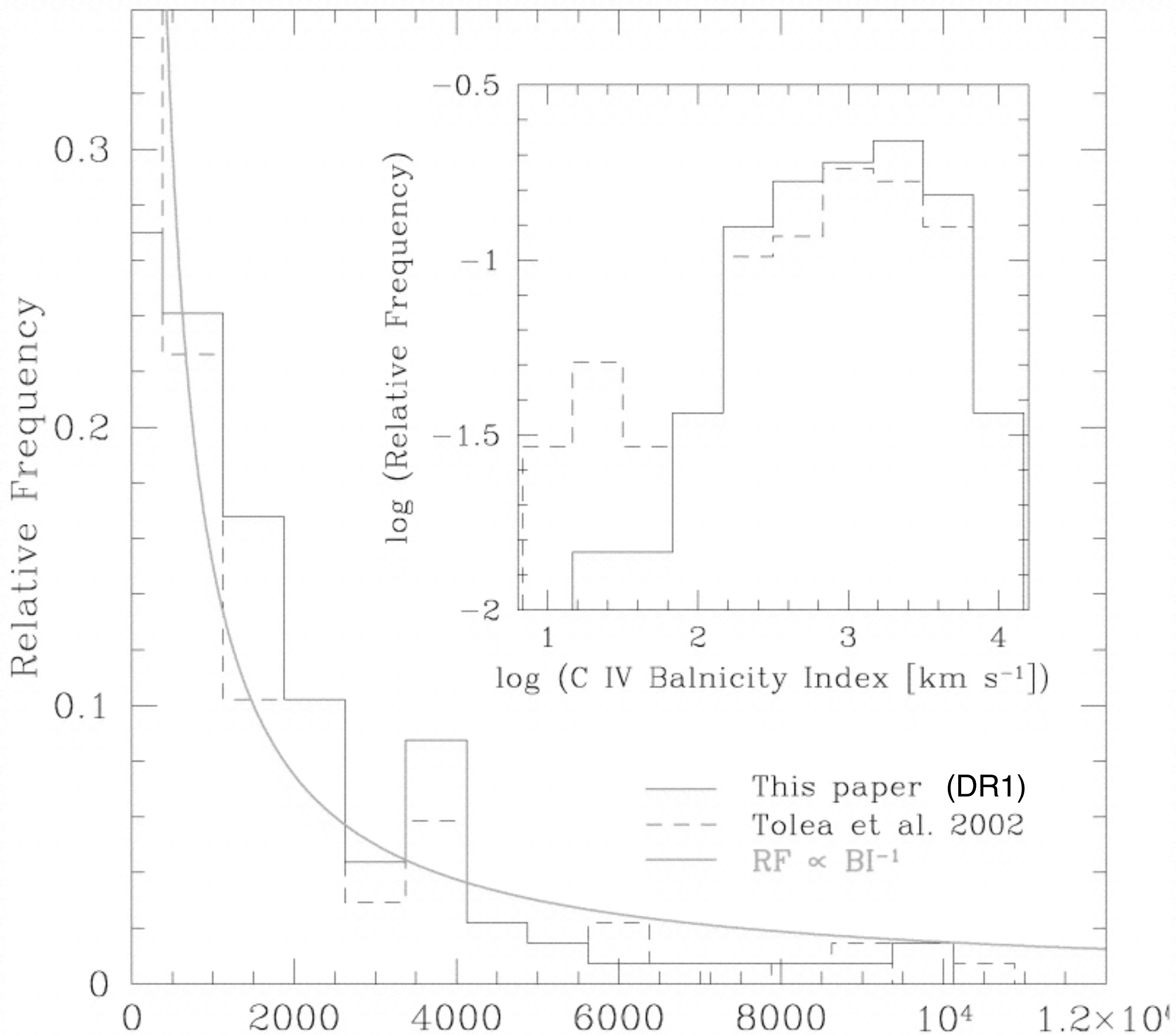
- Single, isolated lines. (19/41)
- Multiple, blended lines. (15/41)
- Broad, blended trough. (7/41)

  (But only 4 have FWHM > 1000 km s^{-1}, and none qualify as BALQSOs.)



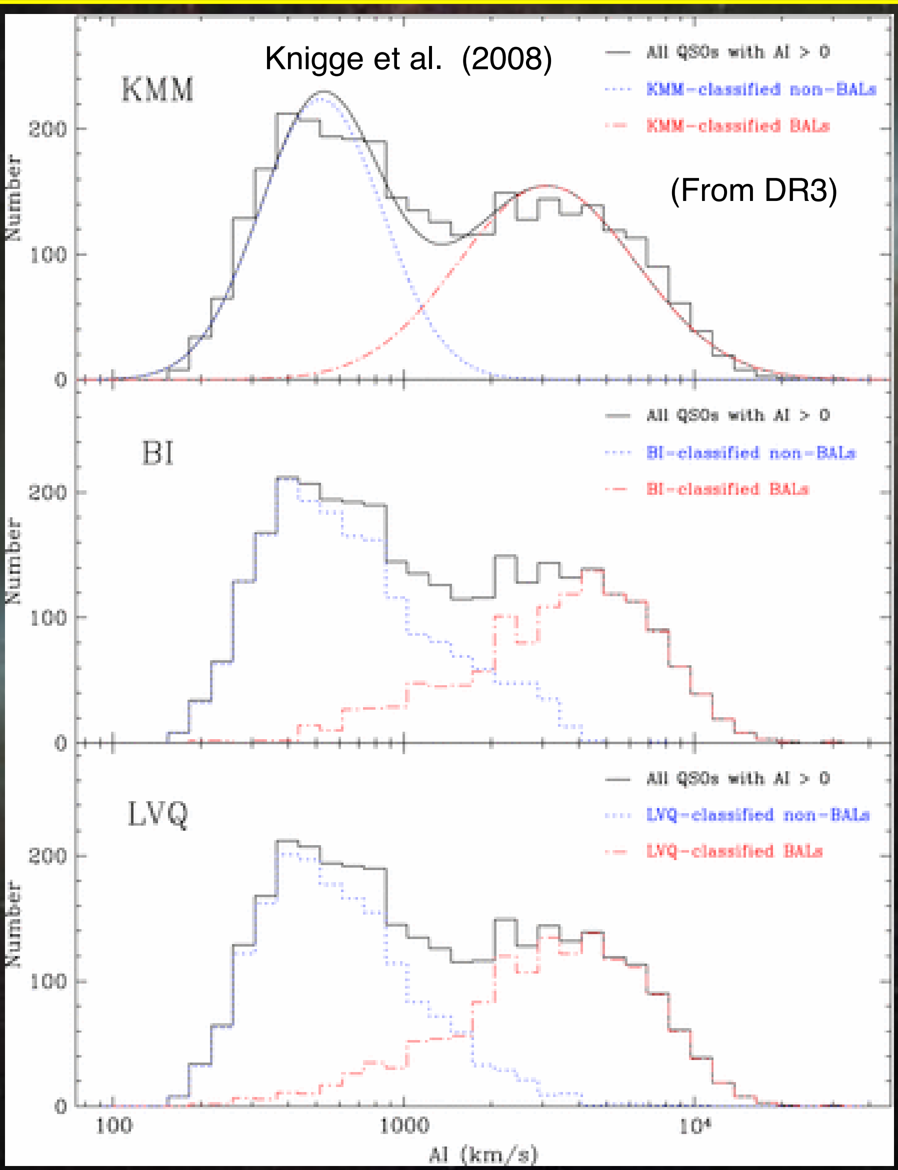
Absorption-trough Frequency in SDSS Quasars

- ★ Narrow absorption troughs are more common.
- ★ Perhaps at low levels the BAL and associated absorbers are related phenomena.



Reichard et al. (2003)

Bimodal Distribution of Absorption Line Widths



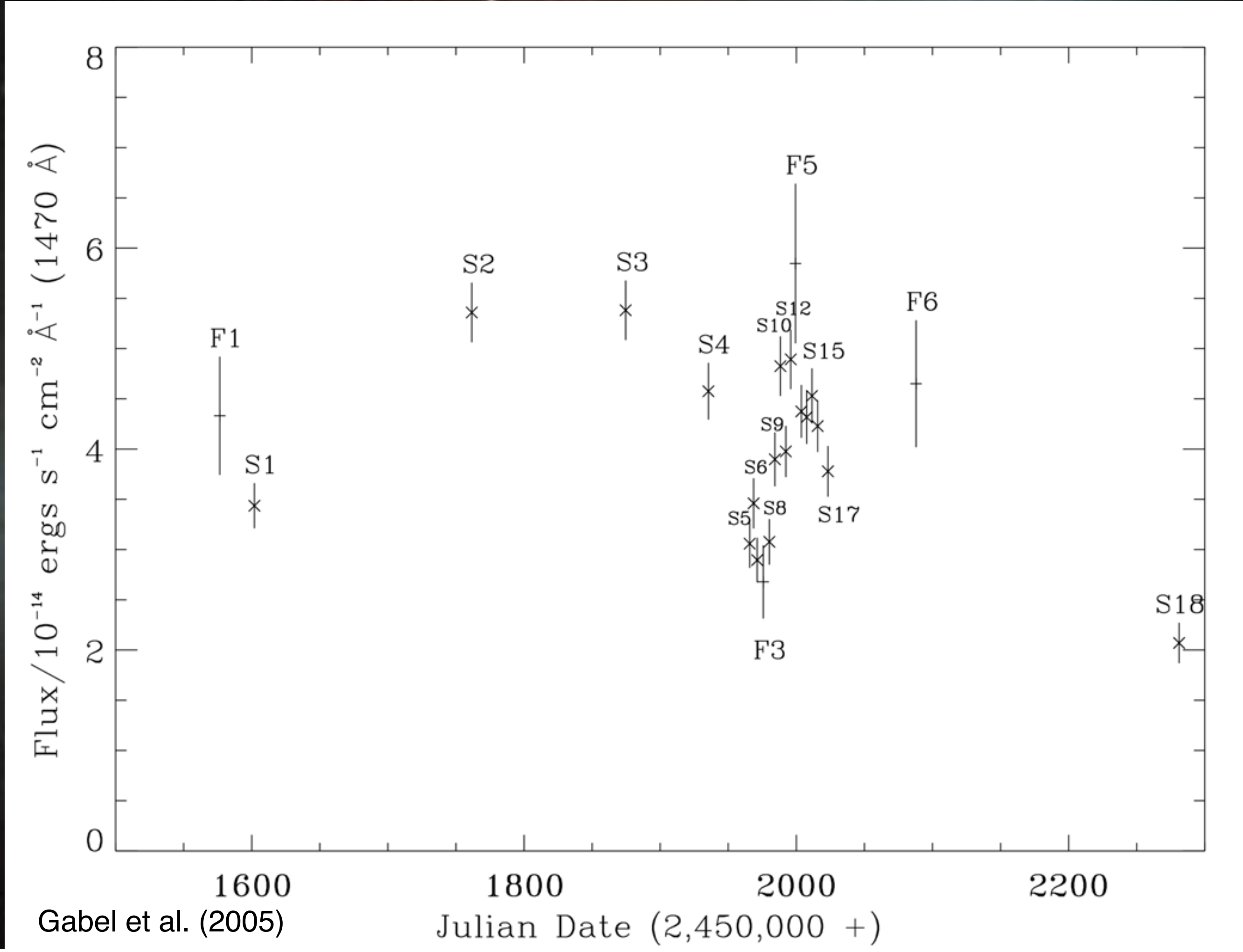
Where is the Outflowing Gas?

- **Thermally driven wind from the obscuring torus (Krolik & Kriss 1995, 2001).**
  - Gas should lie at radii of ~1 pc, depending on central luminosity.
  - It should be visible both in emission/reflection and in absorption.
  - Outflow velocities will be on the order of hundreds of km/s.

- **Winds from the accretion disk, either magnetically driven (Königl & Kartje 1994; Proga 2000) or radiatively driven (Murray et al. 1995; Proga 2000).**
  - Gas should lie at distances of 10^{15} cm.
  - Terminal outflow velocities can be high, tens of km/s.

Monitoring Observations are the Key

"Team NGC 3783" used Chandra, STIS, and FUSE to monitor NGC 3783 over 23 months from 2000 to 2002.

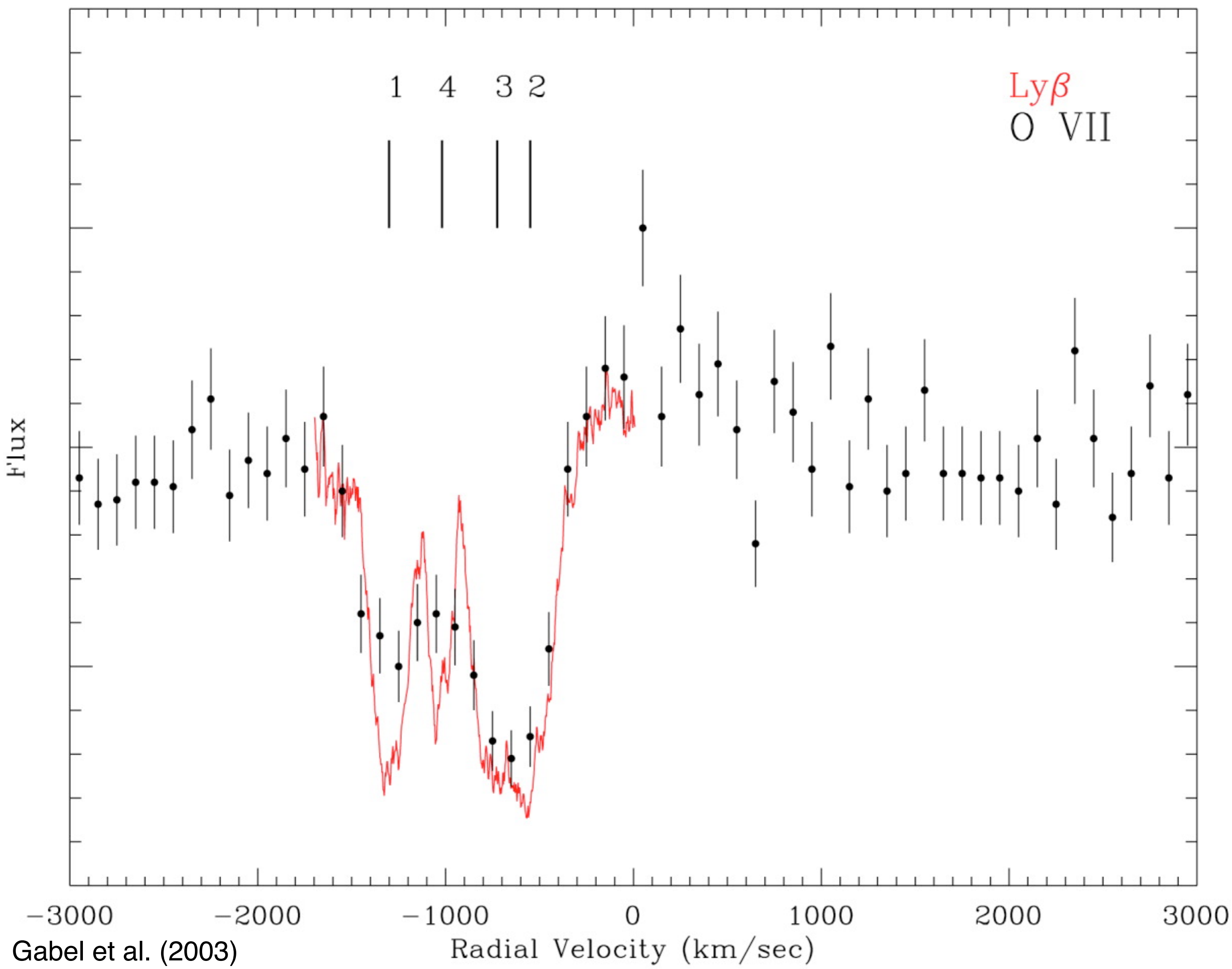


Gabel et al. (2005)

NGC 3783–UV vs. X-ray Absorption

From Gabel et al. (2003):

★ The UV (Lyβ) and X-ray (OVII) absorption have similar kinematics.



Gabel et al. (2003)

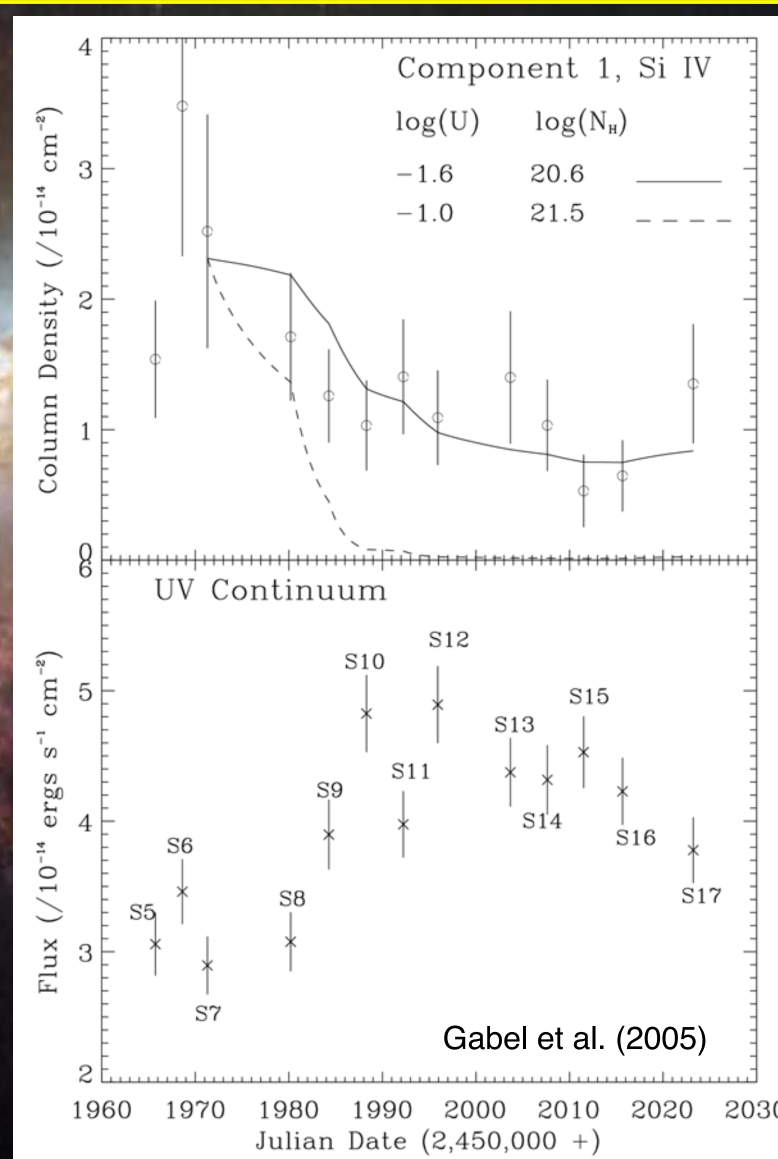
Ionization/Recombination Times ⇒ Density

From Gabel et al. (2005):

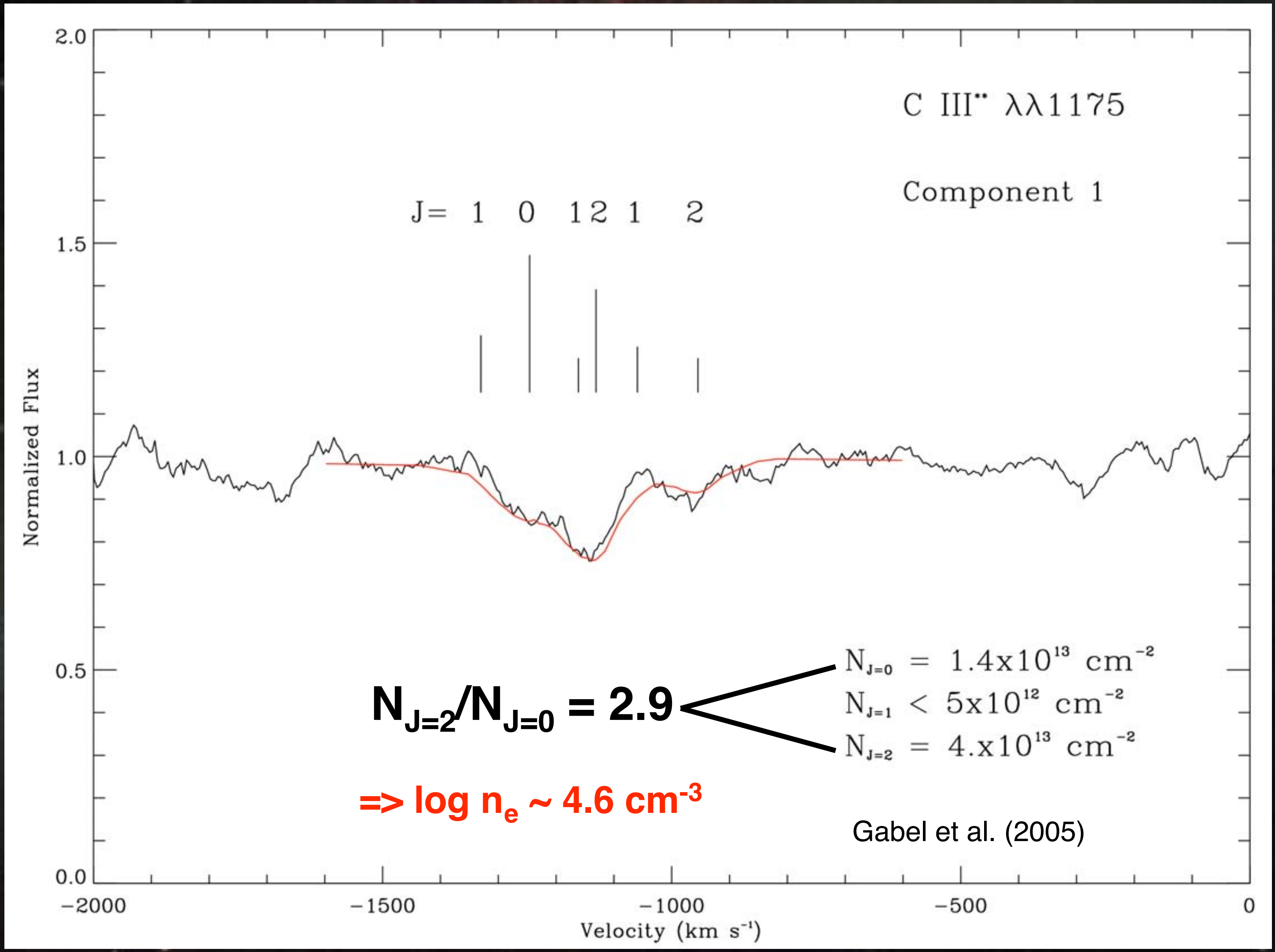
★ Modeling the response to flux variations gives the gas density.

★ Gas density + photoionization models give the distance of the gas.

★ For Component 1 in NGC 3783, the gas lies at a radial distance of ~25 pc.



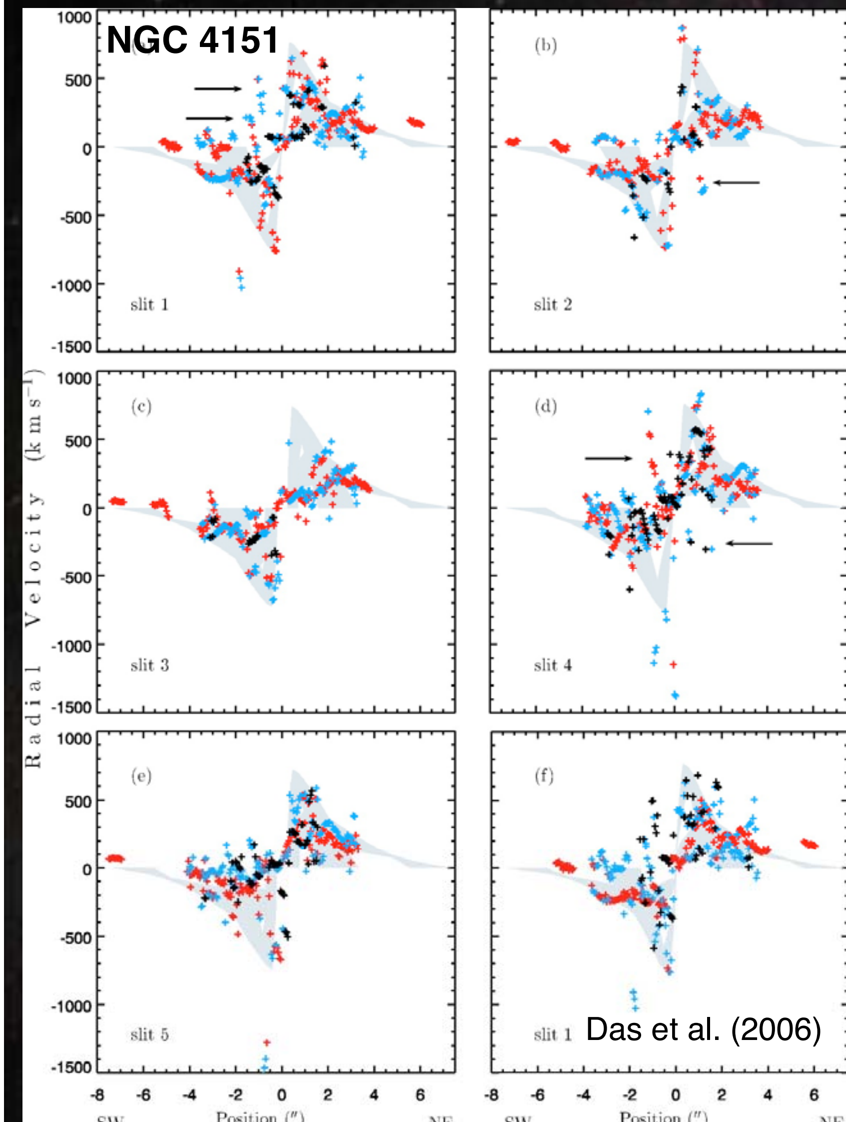
C III λ1176—a Density Diagnostic

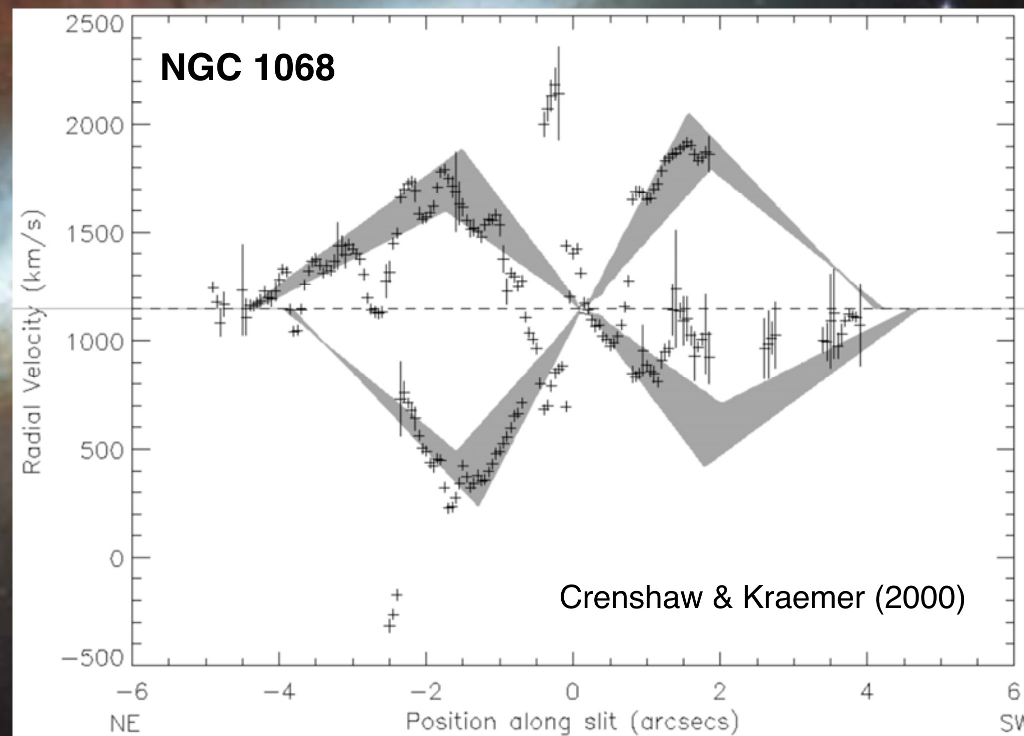


Most AGN Outflows Arise near the NLR

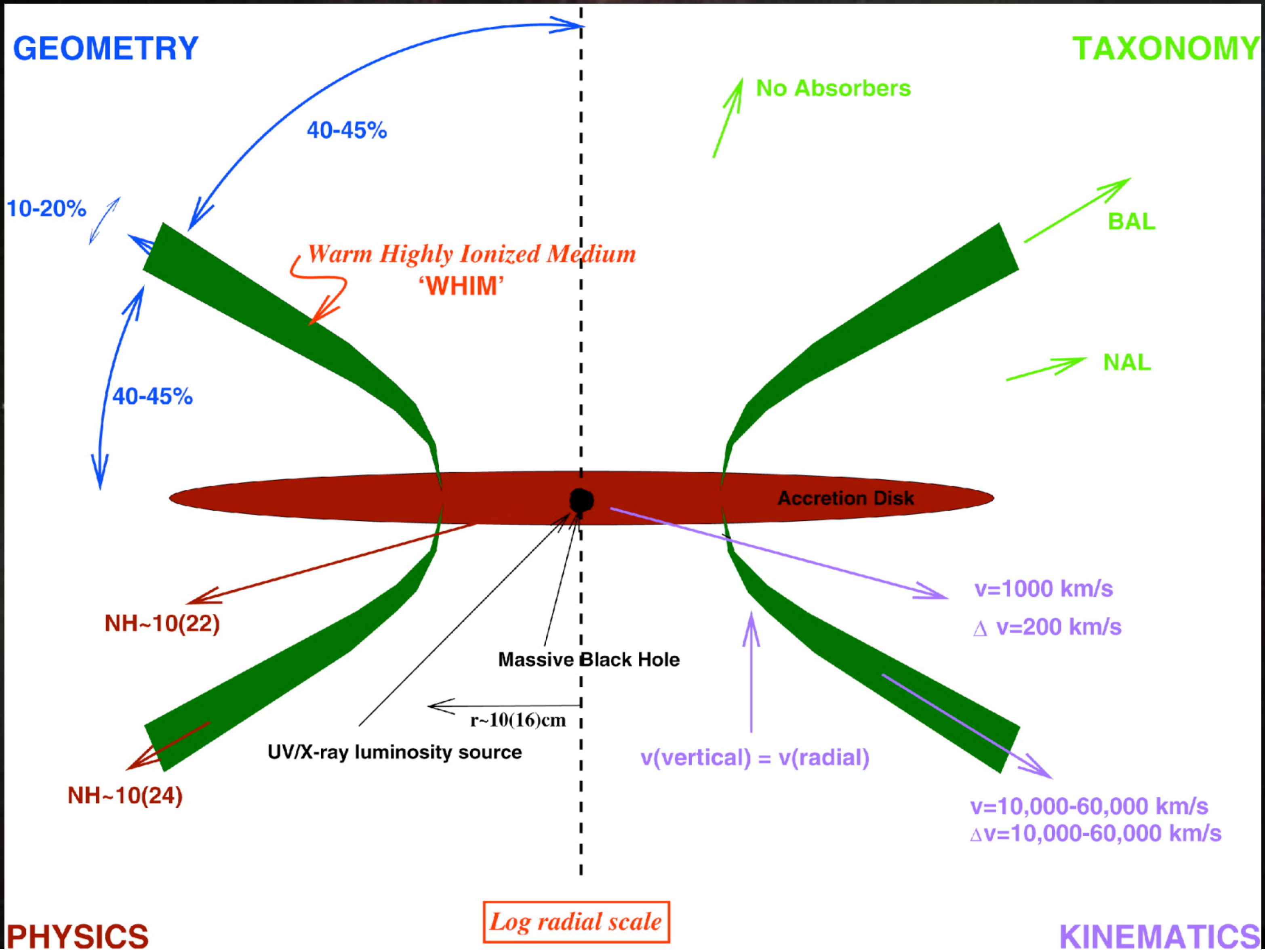
- **Two measures of density from the NGC 3783 campaign place the gas at tens of parsecs from the nucleus (Gabel et al. 2005).**
- **Monitoring of absorption variability in NGC 4151 also suggests distances of tens of parsecs (Kriss et al. 1997; Espey et al. 1998).**
- **Kinematics of the UV absorbers are similar to those of the NLR (Crenshaw & Kraemer 2005).**
- **But, does the gas escape?**
  - Velocities are high enough …
  - But entrainment, mass loading, and confinement can prevent it—
    - The extended NLR of NGC 4151 appears to be at a standstill at 290 pc (Crenshaw et al. 2000).

Outflows in the NLRs of NGC 4151 & NGC 1068

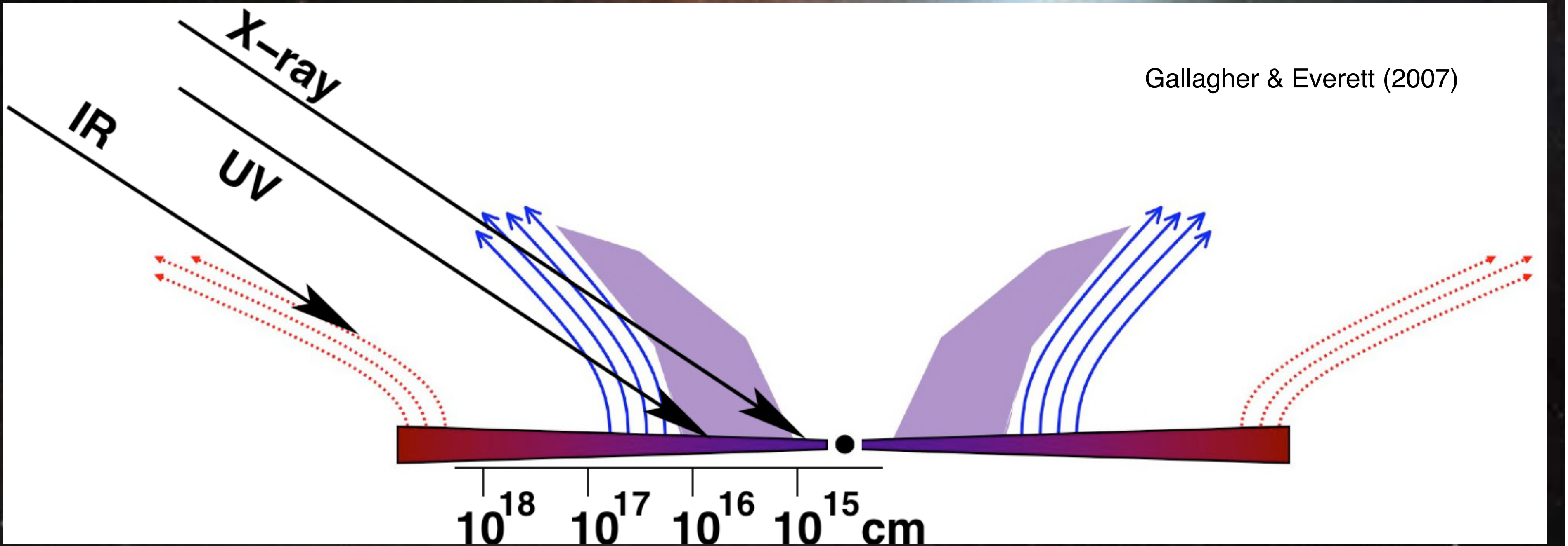




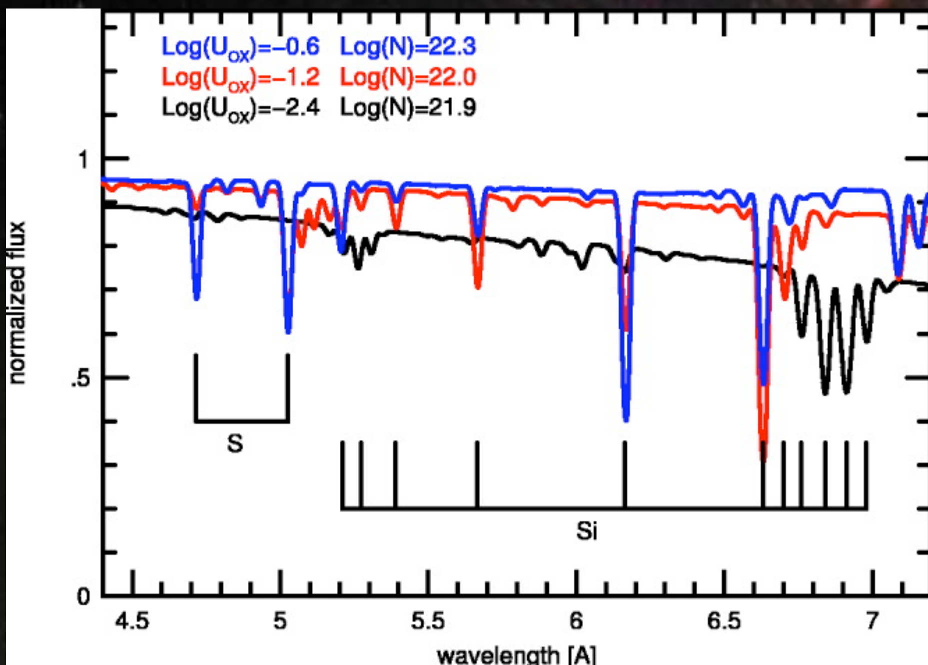
The Elvis Quasar Model (2000)

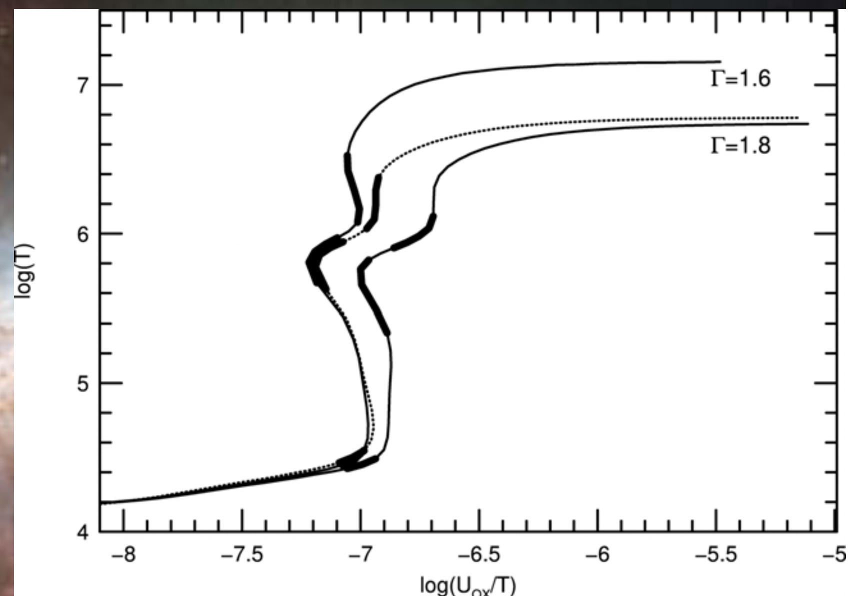


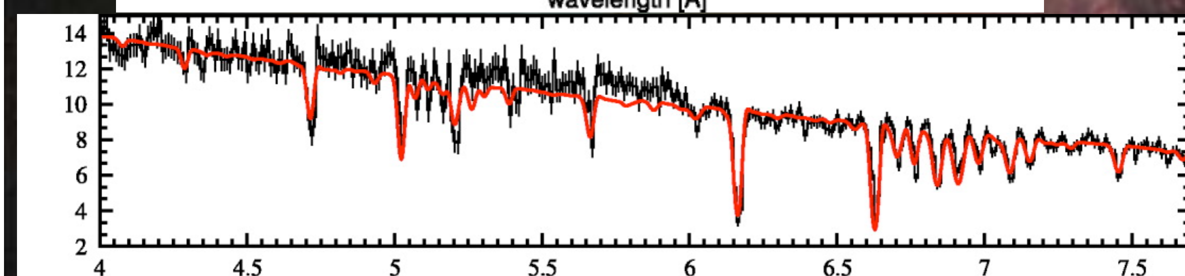
Disk-wind Model for BALQSOs



A Thermally Driven Wind in NGC 3783?







Several ionization stages of S and Si are all present.

The best-fitting set of models are all distributed along the vertical, marginally stable branch of the equilibrium curve, as suggested by Krolik & Kriss (2001).

Netzer et al. (2003)

Summary

- ★ **Outflows are common in AGN. More than half show outflowing absorbing gas in both the UV and the X-ray.**
- ★ **Outflow velocities are typically hundreds to thousands of km/s.**
- ★ **Outflows typically show a broad range of temperatures and ionization parameters in the absorbing gas.**
  - **Most UV absorption is due to lower ionization, lower column density gas than that causing the X-ray absorption.**

  ⇒ UV-absorbing gas is due to higher density clumps embedded in an X-ray absorbing wind?
- ★ **Possible origins for the outflowing gas range from the accretion disk to the obscuring torus. There may well be two populations of absorbers:**
  - High-velocity, broad troughs may originate in a disk wind.
  - Lower velocity, associated absorbers may originate in a thermal wind from the torus.
- ★ **But, the outflows may rarely escape the confines of the host galaxy …**