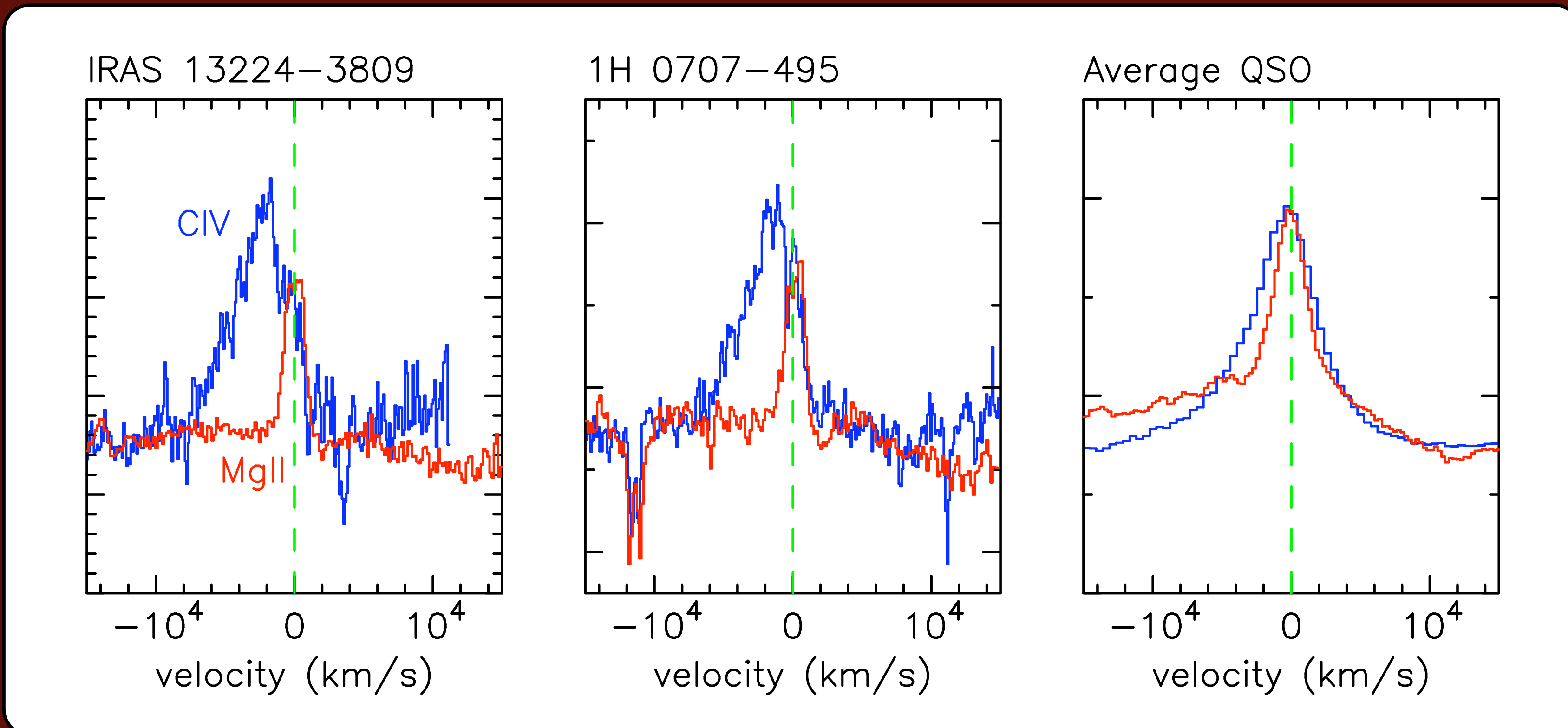
Outflows In Emission

Karen Leighly
OU

What I will be talking about:



Leighly & Moore 2004

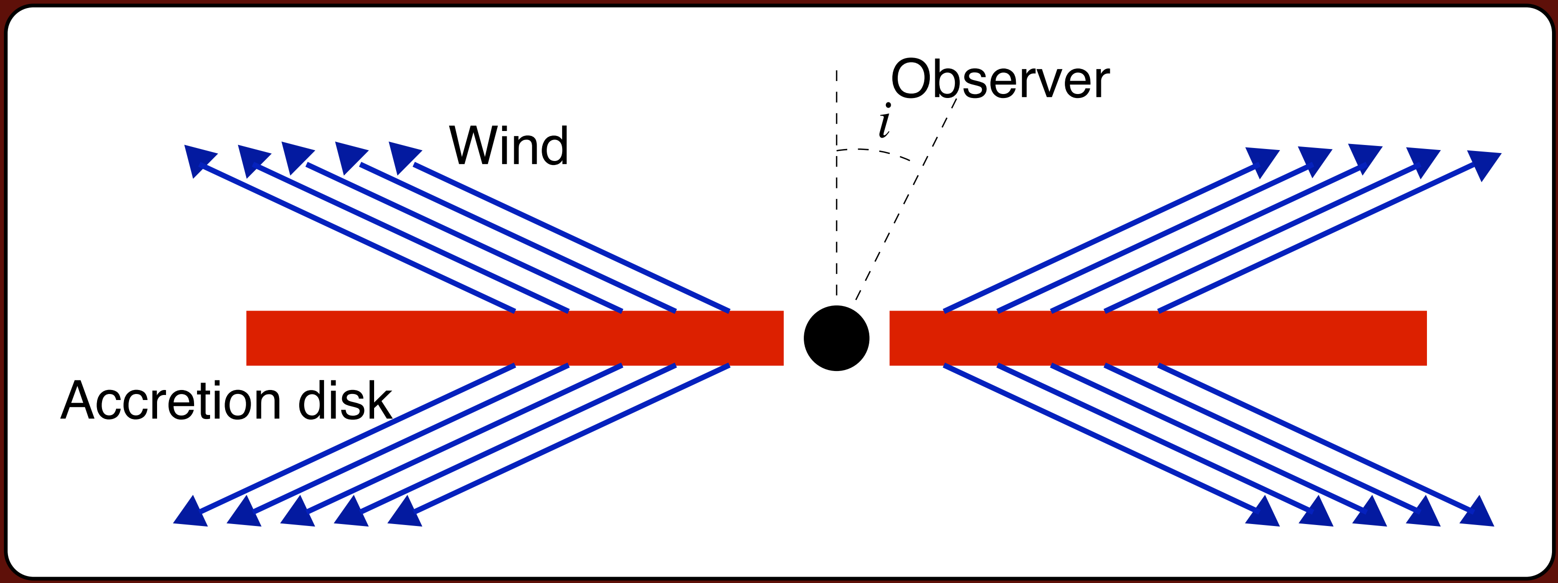
- Blueshifted, UV emission lines.
- Not NLR or coronal lines.

Blueshifted High-Ionization UV Lines: Observations

- Blueshifted high-ionization lines are not uncommon in higher-luminosity radio-quiet AGN.
- E.g., Tytler & Fan 1992; Brotherton et al. 1994; Baldwin et al. 1995; Corbin & Boroson 1996; Baskin & Laor 2005....

Disk-Wind Model

- Blueshifted high-ionization lines emitted in a wind.
- Receding side blocked by optically-thick accretion disk.
- Narrow intermediate- and low-ionization lines emitted by the disk or low-velocity base of the wind.



Leighly & Moore 2004

Why Study Emission?

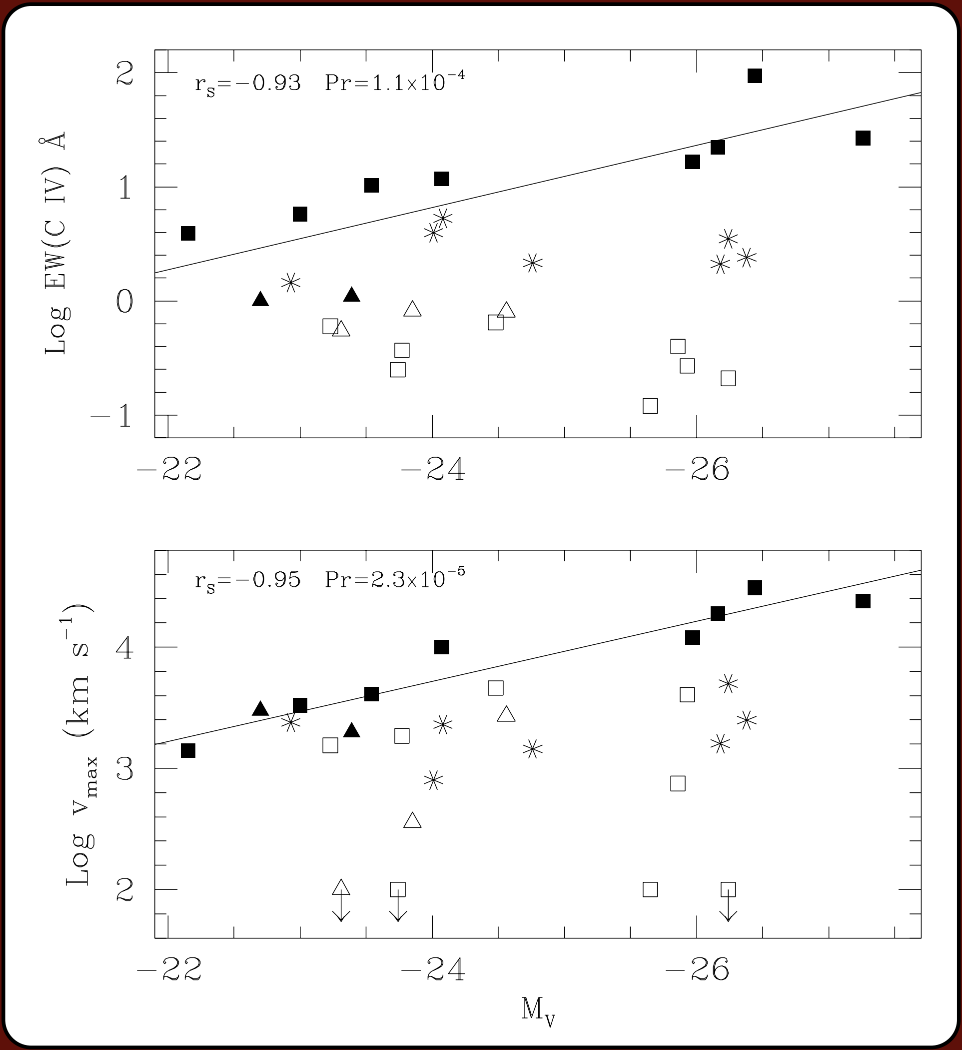
- Absorption is seen only when outflow is in the line of sight.
- Emission may be more isotropic, and so may be seen in any direction (although still angle dependent through projection effects & radiative transfer).
- Blending easier to account for than blanketing?
- Can view X-ray emitting region.

Is Emission the Same as Absorption?

- Laor et al. 1997: prototypical NLS1 I Zw 1 may be a BALQSO not observed through the flow.
- BALQSOs & NLS1s have same parent population? Blueshift in high-ionization lines is more prominent in NLS1s; NLS1s share some features with [low-ionization] BALQSOs: strong FeII/ weak [OIII], predominantly radio-quiet (e.g. Leighly et al. 1997).
- But emission requires high-ish density for efficiency (i.e., BLR density).

Are Outflows the Same in All AGN?

- Luminosity dependence - Laor & Brandt 2002
- Quasar-luminosity objects show strong, high velocity outflows.
- Perhaps Seyfert-luminosity object outflows are higher-ionization (i.e., X-ray)?



Laor & Brandt 2002

Are Outflows the same in all Quasars? Emission Lines:

- **Maybe yes**: Weymann et al. (1991) show that emission lines are very much the same in BALQSOs and non-BALQSOs.
- **Maybe no**: Enhancement of NV, FeII (depending on balnicity) in high-ionization BALQSOs. LoBALs much different.

Are Outflows the same in all Quasars? Emission Lines:

- **Maybe no**: LoBALs have significantly different emission lines (Boroson & Meyers 1992, etc).
- **Maybe no**: Higher fraction of BALQSOs in weak-[OIII] sample (Turnshek et al. 1997).
- **Maybe no**: High-z BALQSOs are strong FeII/weak [OIII] emitters suggesting E1 connection (Yuan & Wills 2003).

Are Outflows the same in all Quasars? X-ray Properties of BALQSOs:

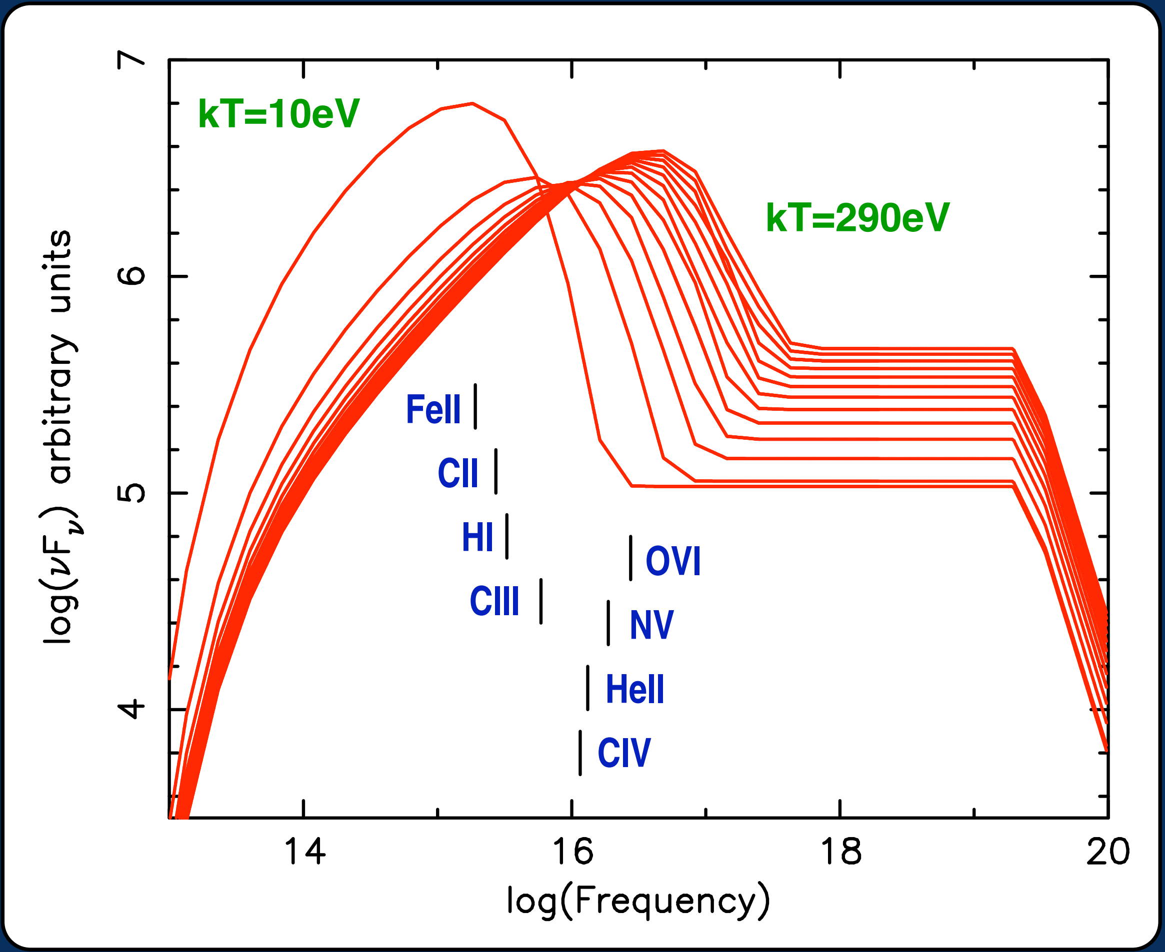
- **Maybe yes**: BALQSO X-ray spectra shows high column densities; correction for that yields normal α_{ox}'s (e.g., Gallagher et al 2002).
- **Maybe no**: Sabra & Hamann 2001 find that after accounting for X-ray absorption, PG 1254+407 is X-ray weak.

Maybe the Spectral Energy Distribution has something to do with it:

- If outflows are accelerated by radiative-line driving, SED could be important.
- Strong UV - important for scattering.
- Weak X-ray - prevents over-ionization of outflow.
- Coronal quenching - Daniel Proga’s talk.

Semi-empirical Spectral Energy Distribution

- Darrin Casebeer created semi-empirical spectral energy distributions parameterized by the UV bump turnover.
- Mean quasar SED has kT~60 eV
- Computed tens of thousands of *Cloudy* models.



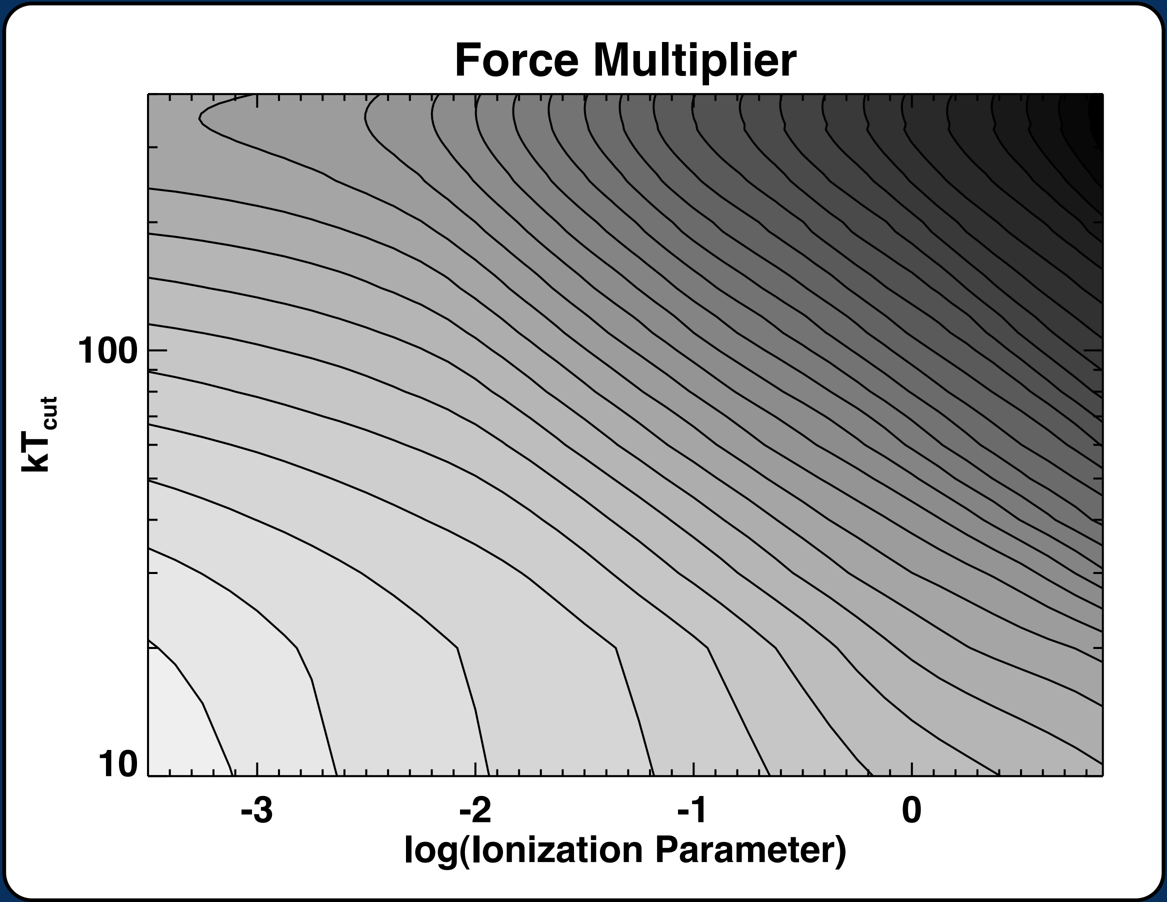
Casebeer, Leighly & Baron 2006

Force Multiplier Computation

- The force multiplier is the ratio of the force due to resonance-line scattering to the force due to Compton scattering.
- I computed the force multiplier as a function of ionization parameter for semiempirical SEDs.

Results

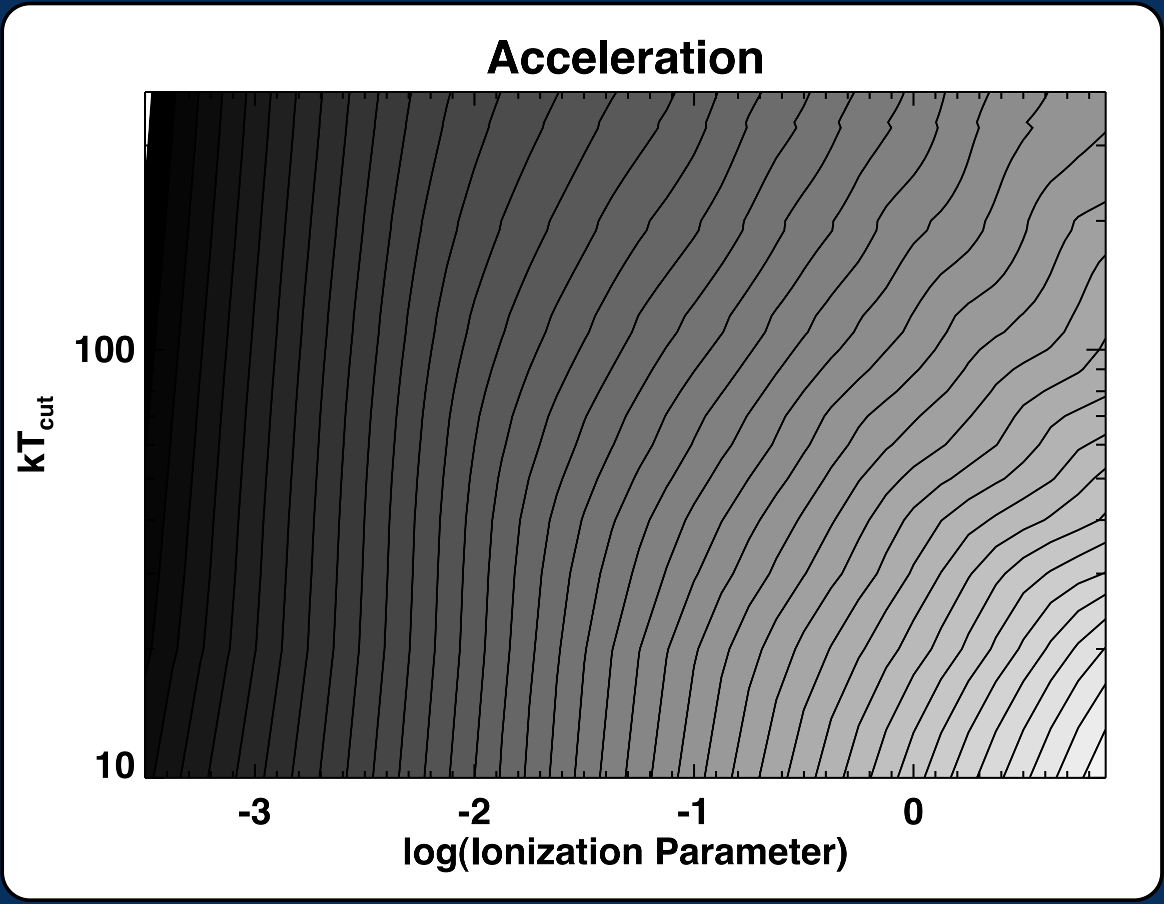
- For a particular ionization parameter force multiplier and accelerations are larger for soft (UV-dominant) SEDs.
- ***More massive, faster outflows expected from softer SEDs.***



Light color - larger value

Results

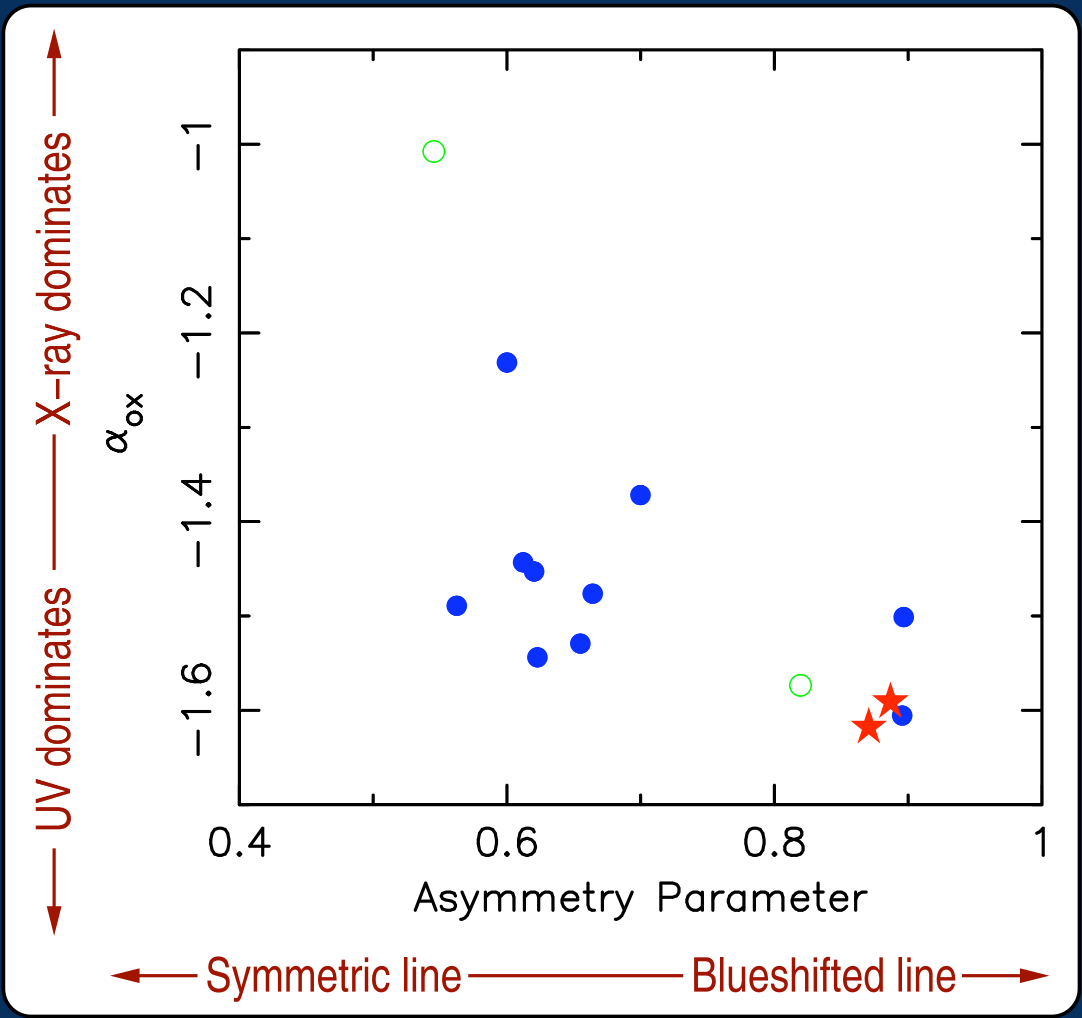
- For a particular ionization parameter force multiplier and accelerations are larger for soft (UV-dominant) SEDs.
- ***More massive, faster outflows expected from softer SEDs.***



Light color - larger value

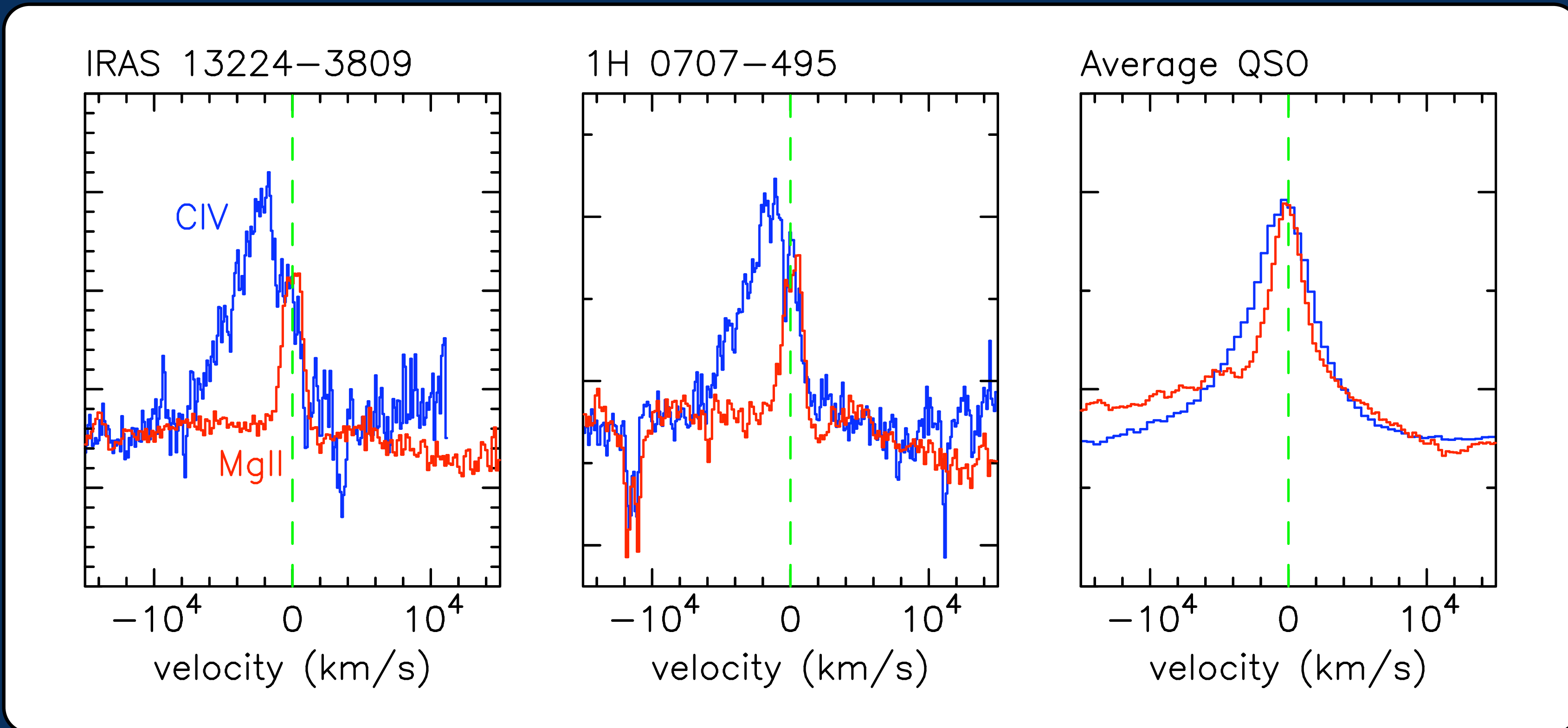
Evidence: Blueshift vs α_{ox}

- Sample of 16 NLS1s with *HST* spectra.
- Asymmetry parameterized by the fraction of the line blueward of the rest wavelength.
- α_{ox} is the point-to-point slope between 2500Å and 2 keV.
- => Objects with blueshifted lines have UV-dominant spectra.



Leighly & Moore 2004

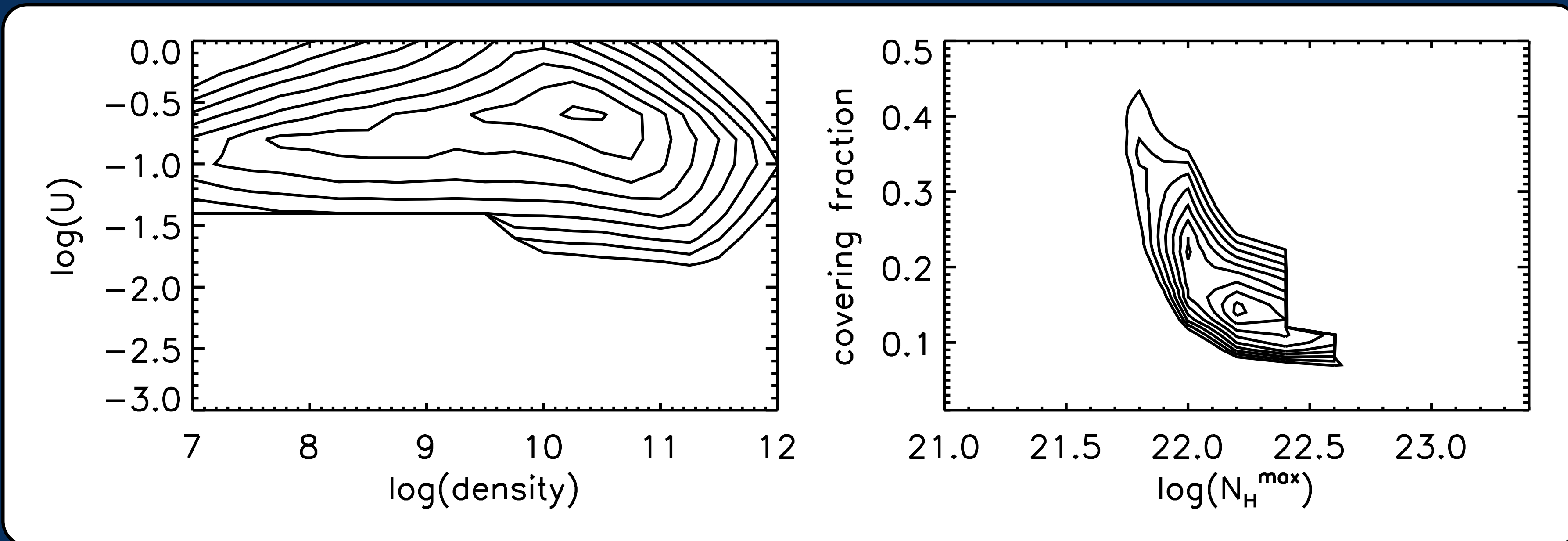
Modeling UV Emission in Extreme NLS1s



Leighly & Moore 2004

- Template developed from CIV applied to Lyα, NV, and 1400 A feature.

Best Wind Solution



Leighly 2004

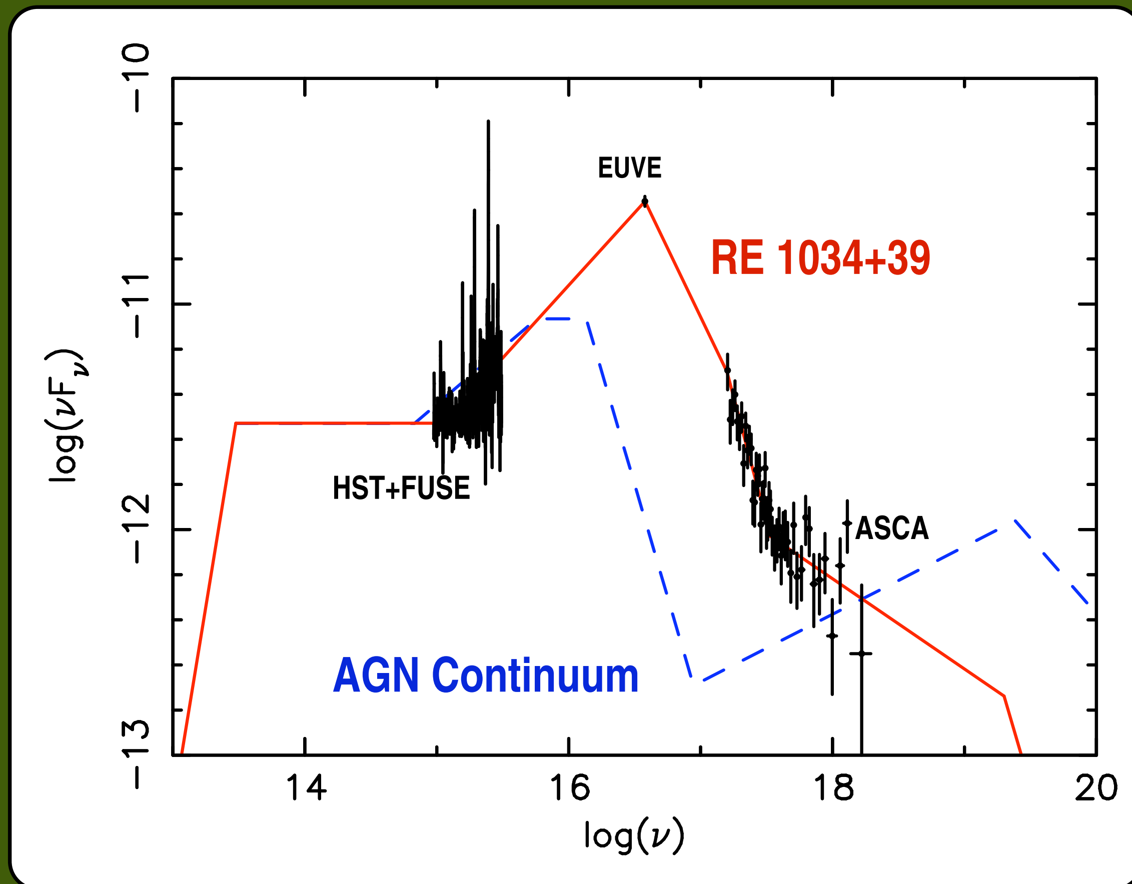
- ***X-ray Weak Continuum*** & Enhanced metallicity
- Wide range of densities => density not fine-tuned.
- log(U)=-1.2 to -0.2 & column density=$10^{21.4}$ cm^{-2}

So if SED is Important:

- Objects with flat α_{ox} should have no winds.
- Objects with steep α_{ox} should have winds.
- Note that α_{ox} is more easily measured in emission-line objects - potential model dependence in BALQSOs due to absorption. Also, loBALs are very highly absorbed.

RE 1034+39

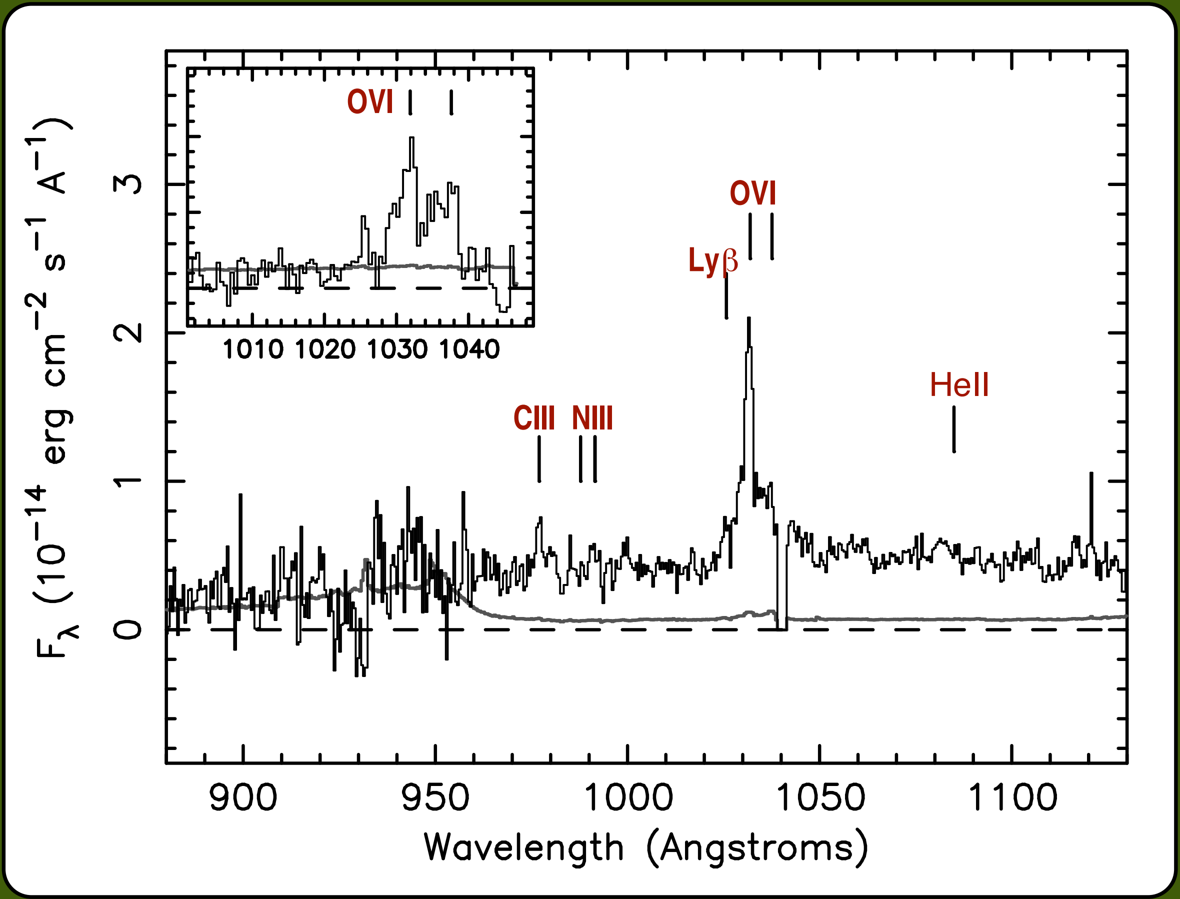
- RE 1034+39 is a low-luminosity NLS1 known for its hard (X-ray dominant) SED.
- Coordinated *FUSE*, *EUVE*, and *ASCA* observations.



Casebeer, Leighly & Baron 2006

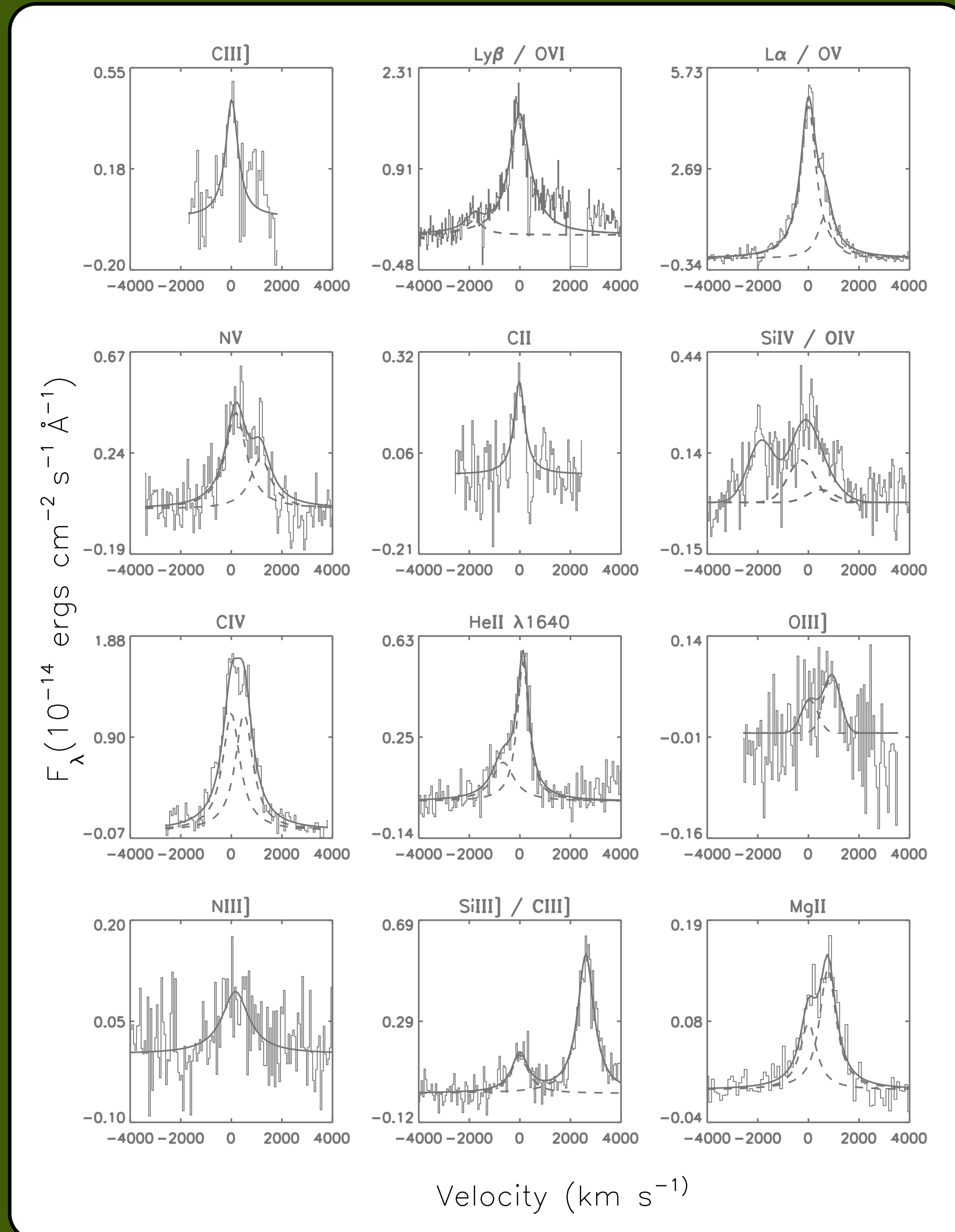
FUSE Spectrum

- Strong high-ionization line emission (e.g., OVI).
- Narrow and symmetric lines - no wind.
- Weak low-ionization line emission.



Casebeer, Leighly & Baron 2006 (in press)

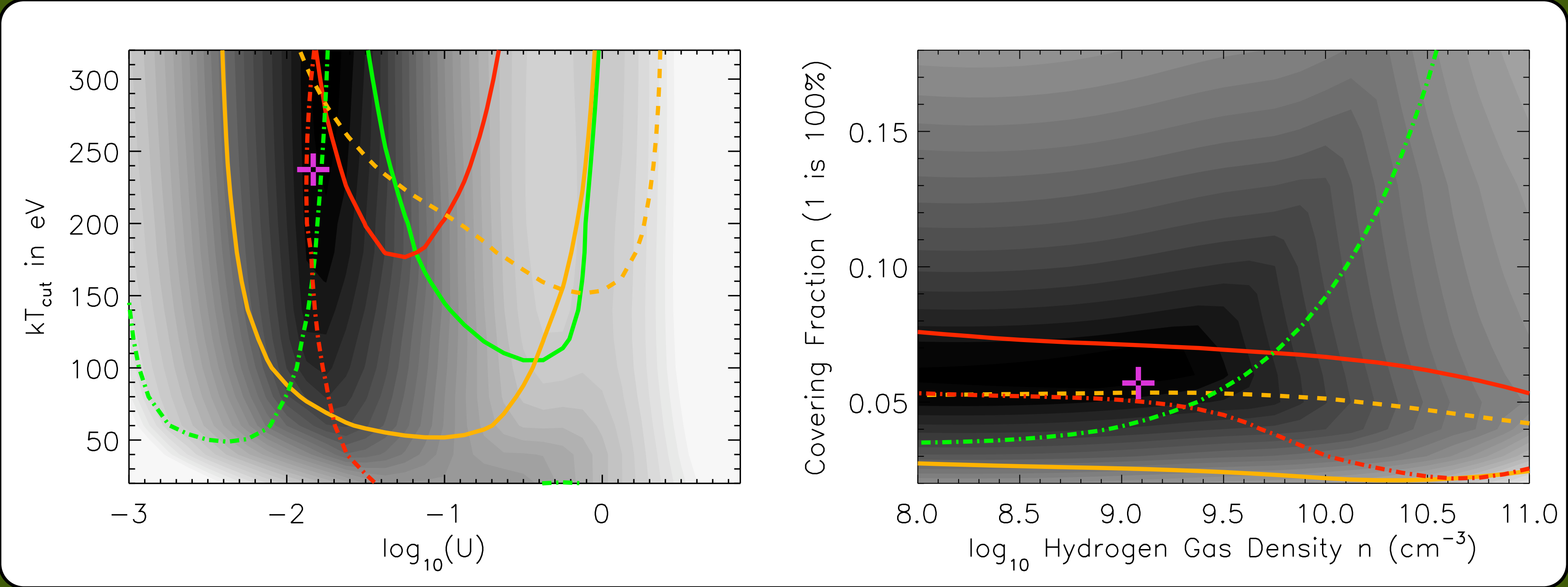
- All the lines are narrow and symmetric - no wind.



Casebeer, Leighly & Baron 2006

Cloudy Modeling

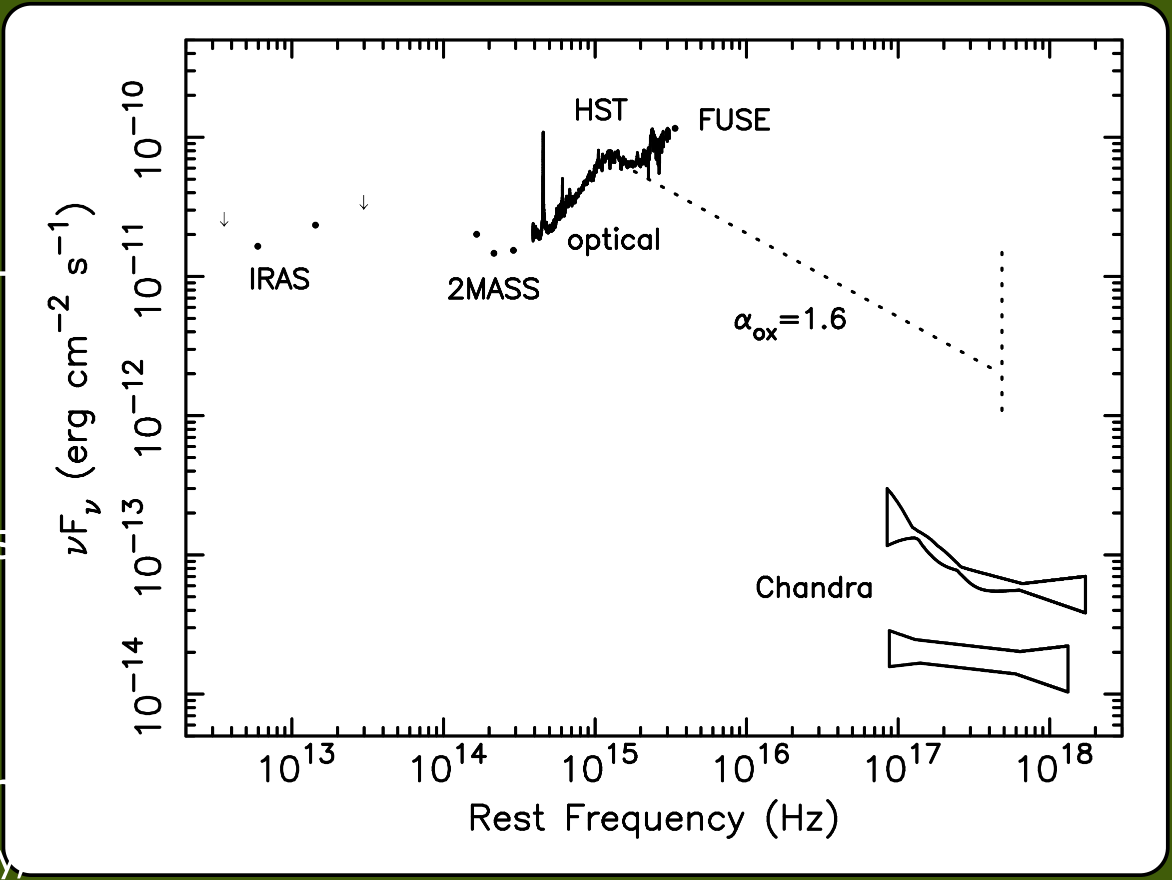
- Cloudy modeling shows that emission-line strengths and ratios are best produced by hard spectral energy distribution.



Casebeer, Leighly & Baron 2006

PHL 1811

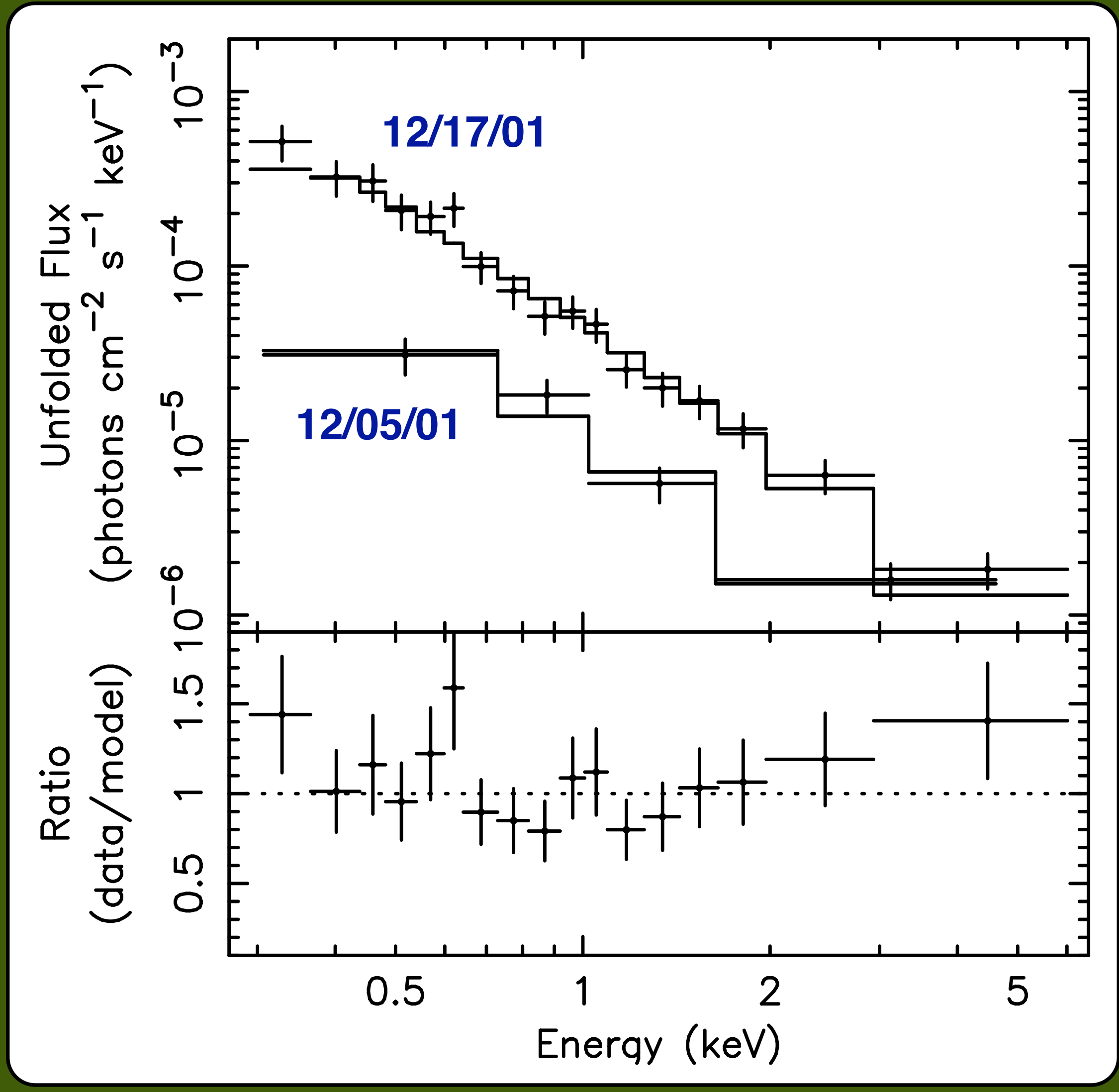
- Optically the second brightest quasar beyond z=0.1 (z=0.192).
- Undetected in *ROSAT* All Sky Survey.
- Coordinated *HST* & *Chandra* observations.
- Anomalously X-ray weak in **6** observations between 1990 and 2005 (Leighly, Choi, Grupe, Prescott, Matsumoto, Biesemeyer in prep).



Leighly et al. 2006, Leighly et al. 2001

Intrinsically X-ray Weak

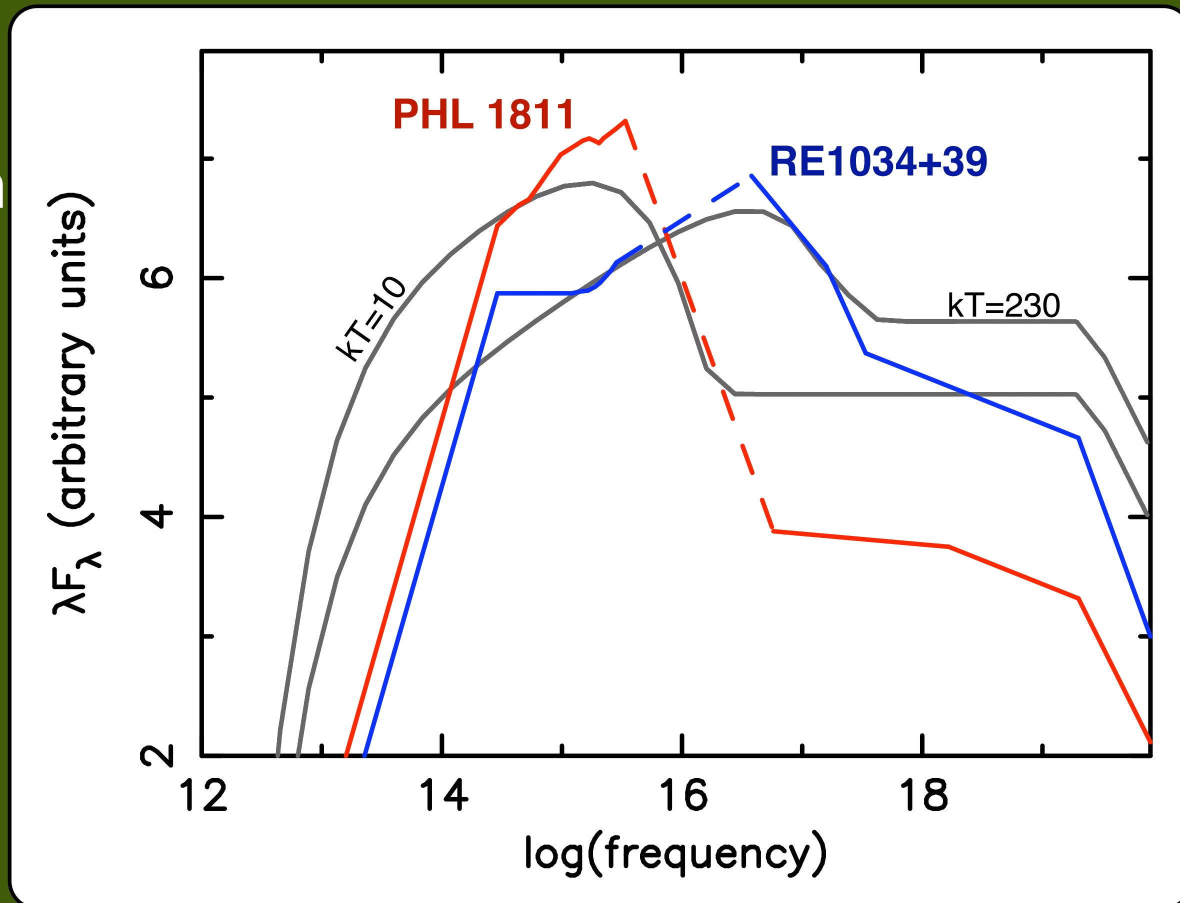
- Steep spectrum, so not absorbed.
- Variable, so not scattered light.
- => Intrinsically X-ray weak.



Leighly et al. 2006

PHL 1811 vs RE 1034+39

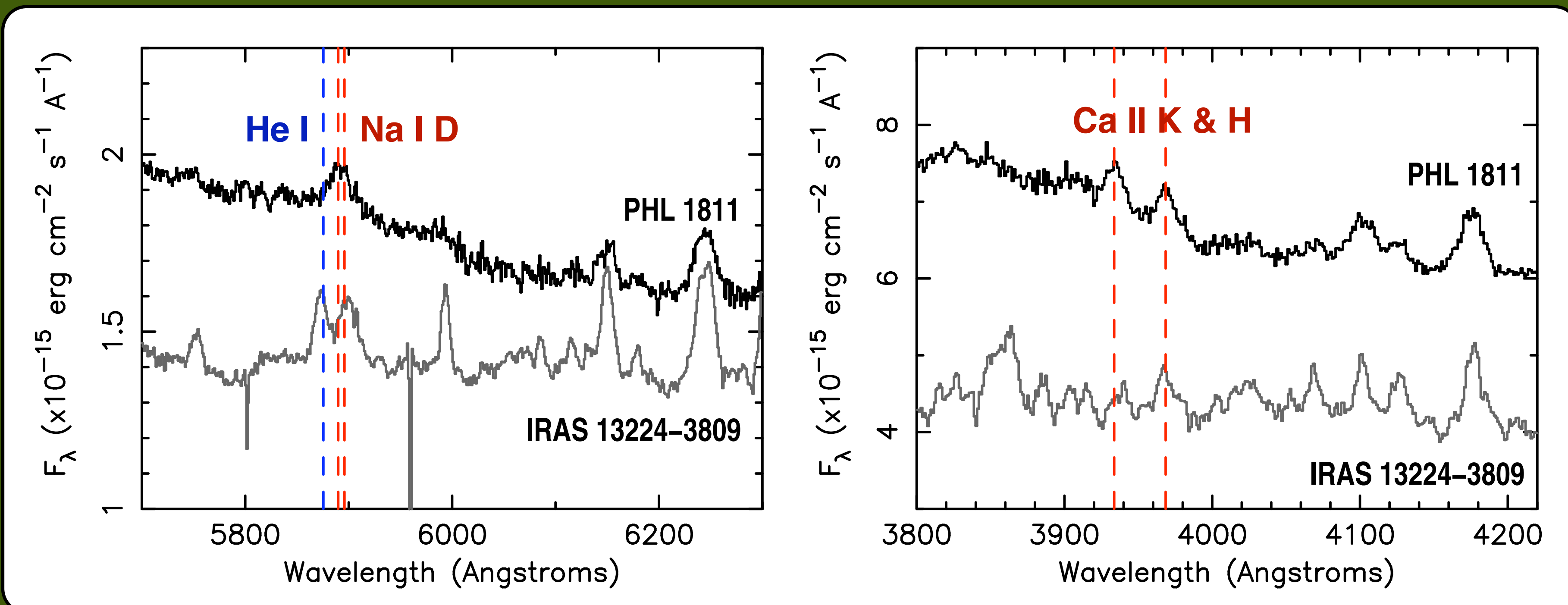
- In contrast with RE 1034+39, PHL 1811 has a very soft (UV-dominant) SED.
- Both objects are ***not*** typical.



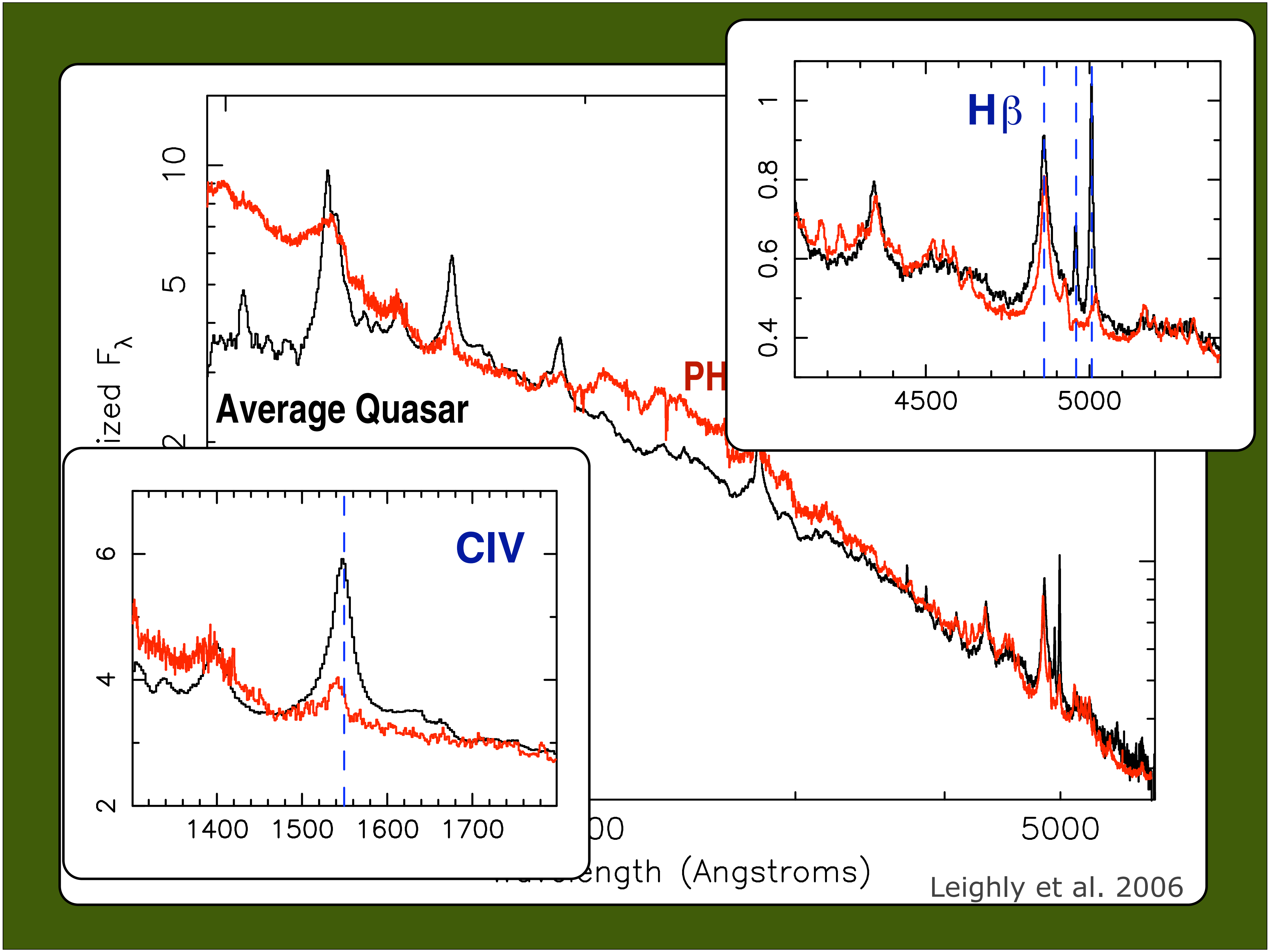
Casebeer, Leighly & Baron 2006, Leighly et al. 2005

Very Low-ionization Lines

- We see very low-ionization lines NaID and CaII H&K that are rarely seen in AGN spectra.



Leighly et al. 2006



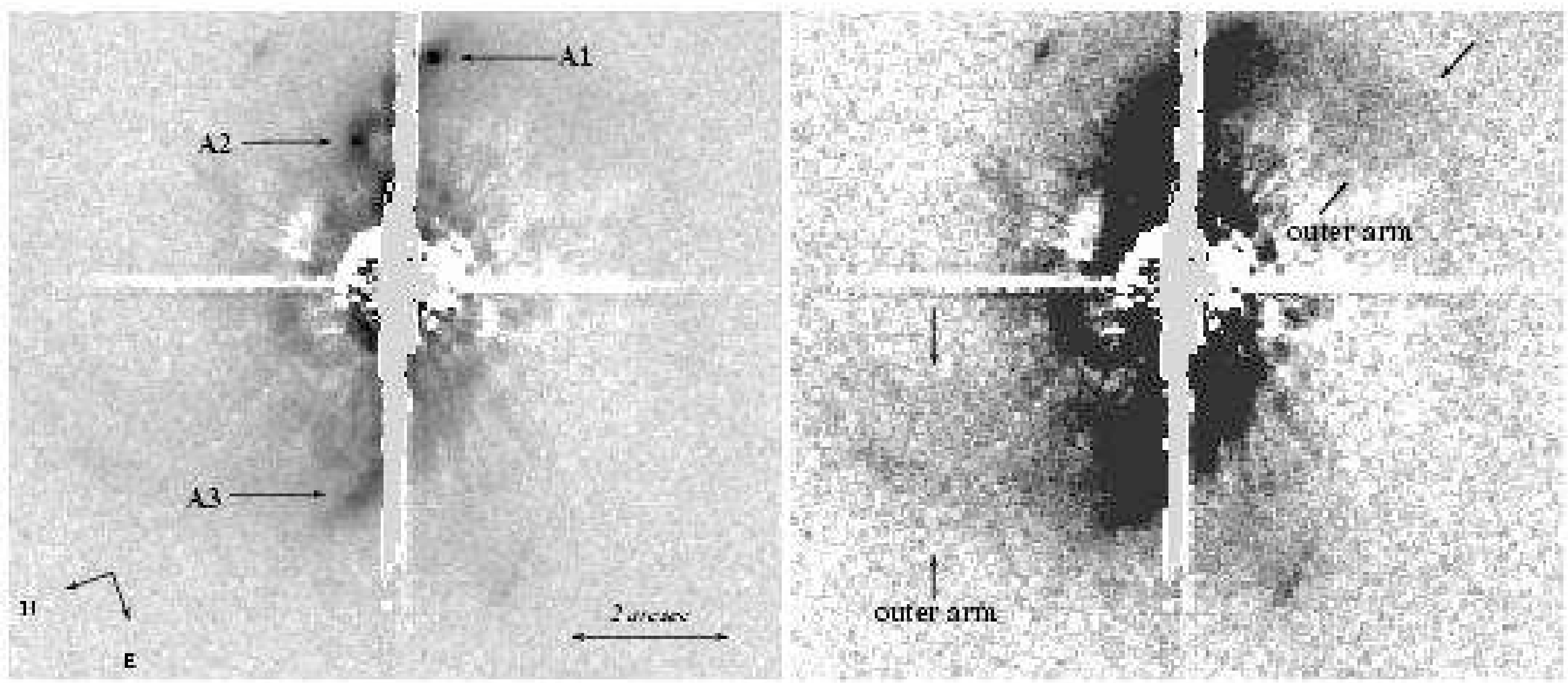
Average Quasar
PH
ized F_λ
10
5
2
00
5000
ength (Angstroms)
Leighly et al. 2006
CIV
6
4
2
1400
1500
1600
1700
Hβ
1
0.8
0.6
0.4
4500
5000

Aside: Weak CIV and Viewing Angle

- It has been suggested that objects like PHL 1811 have low equivalent-width high-ionization lines because they are viewed face on (e.g., Blundell et al. 2003).
- Can't be true: can't gain a factor of 6 via viewing angle. Also, Hß has normal equivalent width, and the continuum is similar to that of an average quasar.

PHL 1811 Host Galaxy

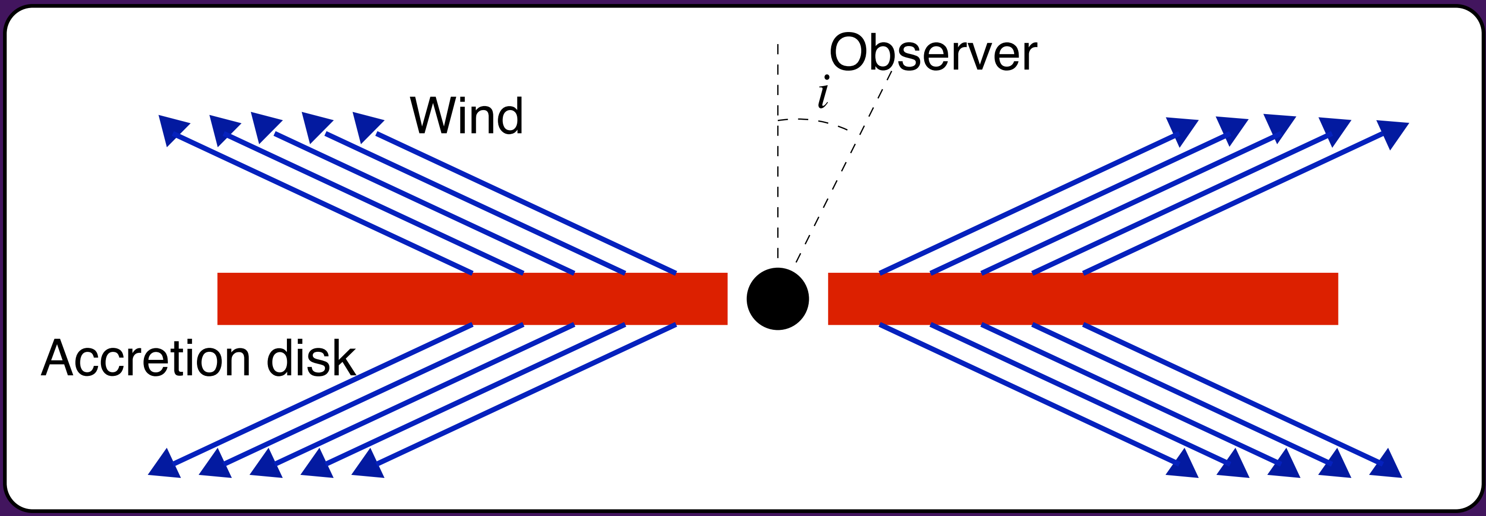
- PHL 1811 has a spiral host galaxy, rather than a luminous elliptical galaxy like most quasars.



Jenkins et al. 2004

Low-ionization Line Emission

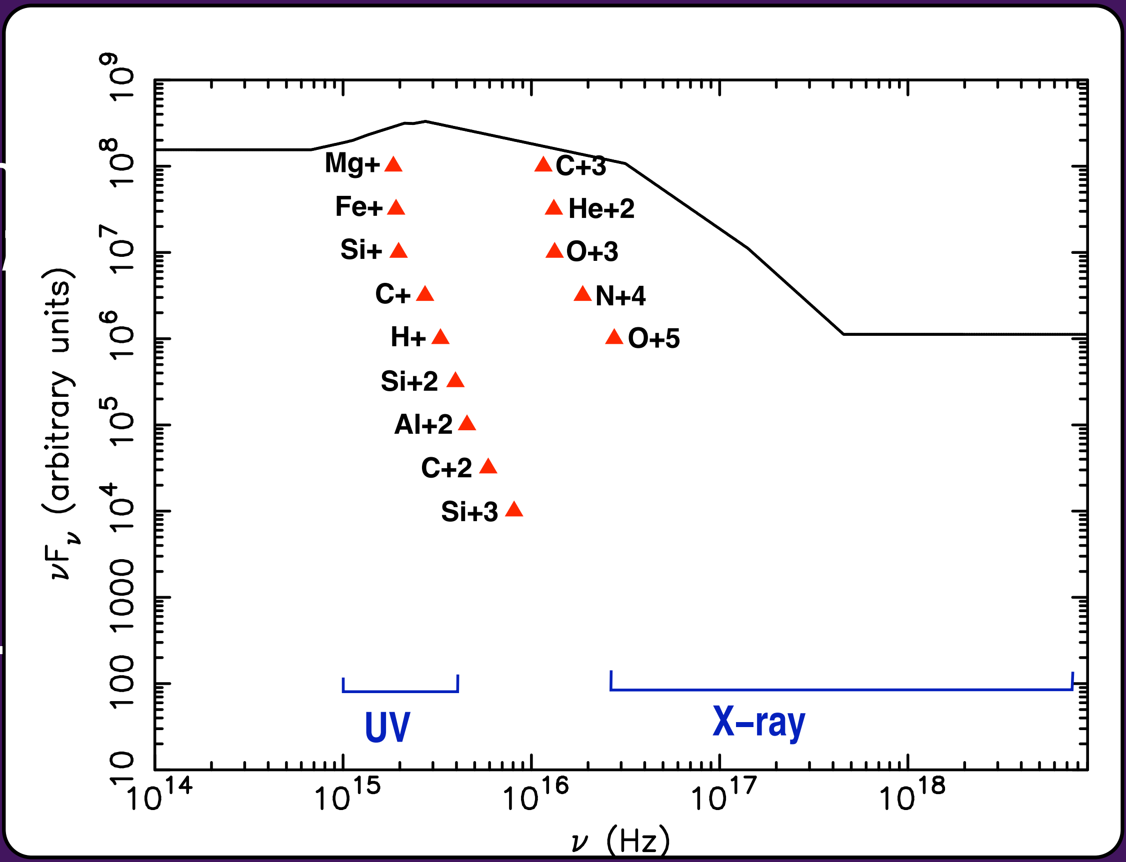
- Outflows trace high-ionization resonance lines predominantly. The low-ionization line emission is also important.
- There is some evidence that the spectral energy distribution also influences the intermediate- and low-ionization line emission.



Leighly & Moore 2004

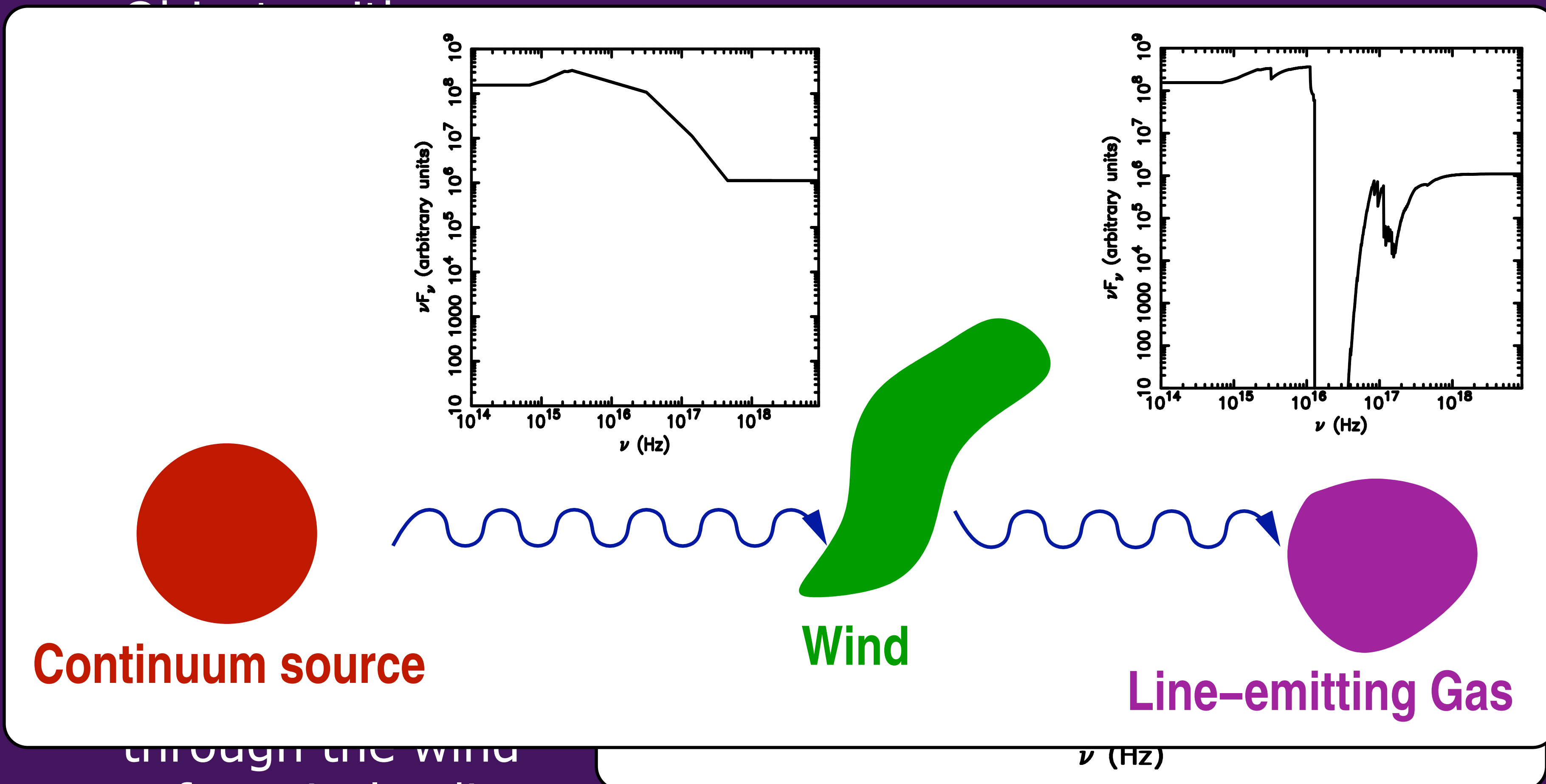
Wind-filtered Continuum

- Objects with blueshifted *high*-ionization lines have strong *low*-ionization lines (e.g., SiII, FeII; e.g. Wills et al. 1999).
- Implies emission very far from the black hole, unless….
- Filtering continuum through the wind softens it, leading to strong low-ionization lines.



Leighly 2004

Wind-filtered Continuum

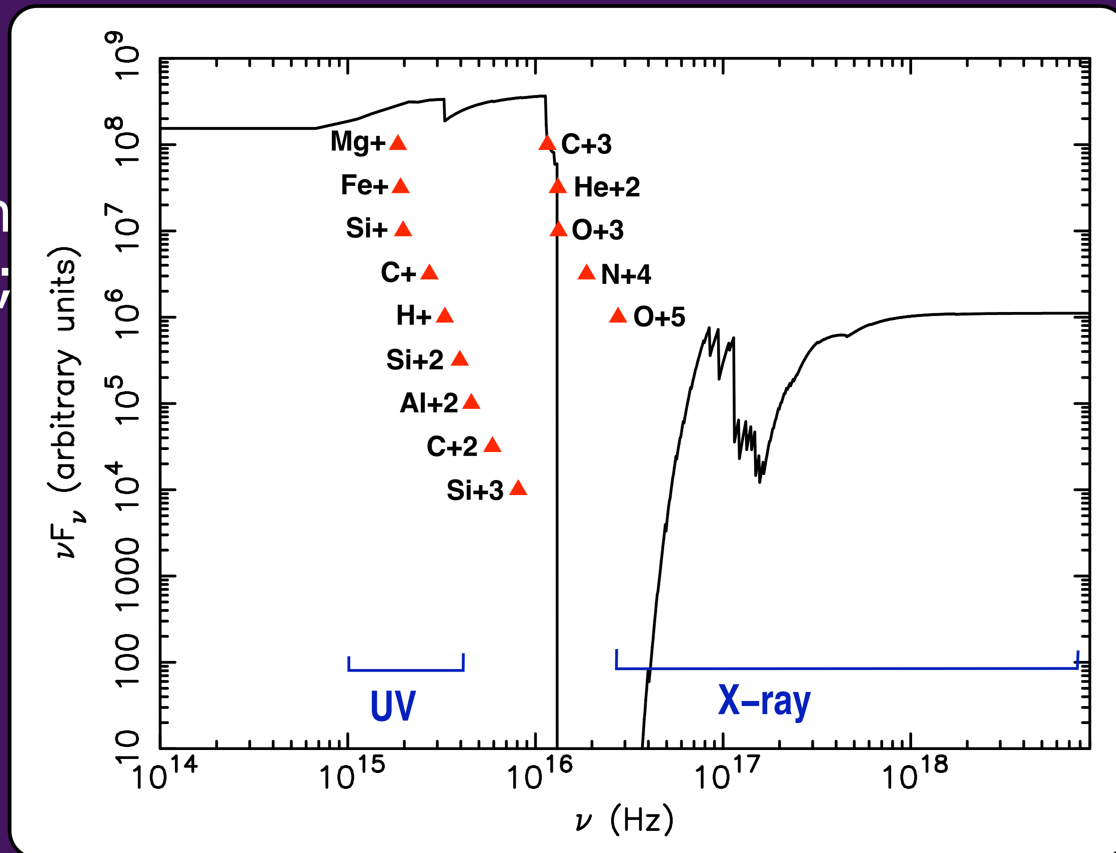


through the wind softens it, leading to strong low-ionization lines.

Leighly 2004

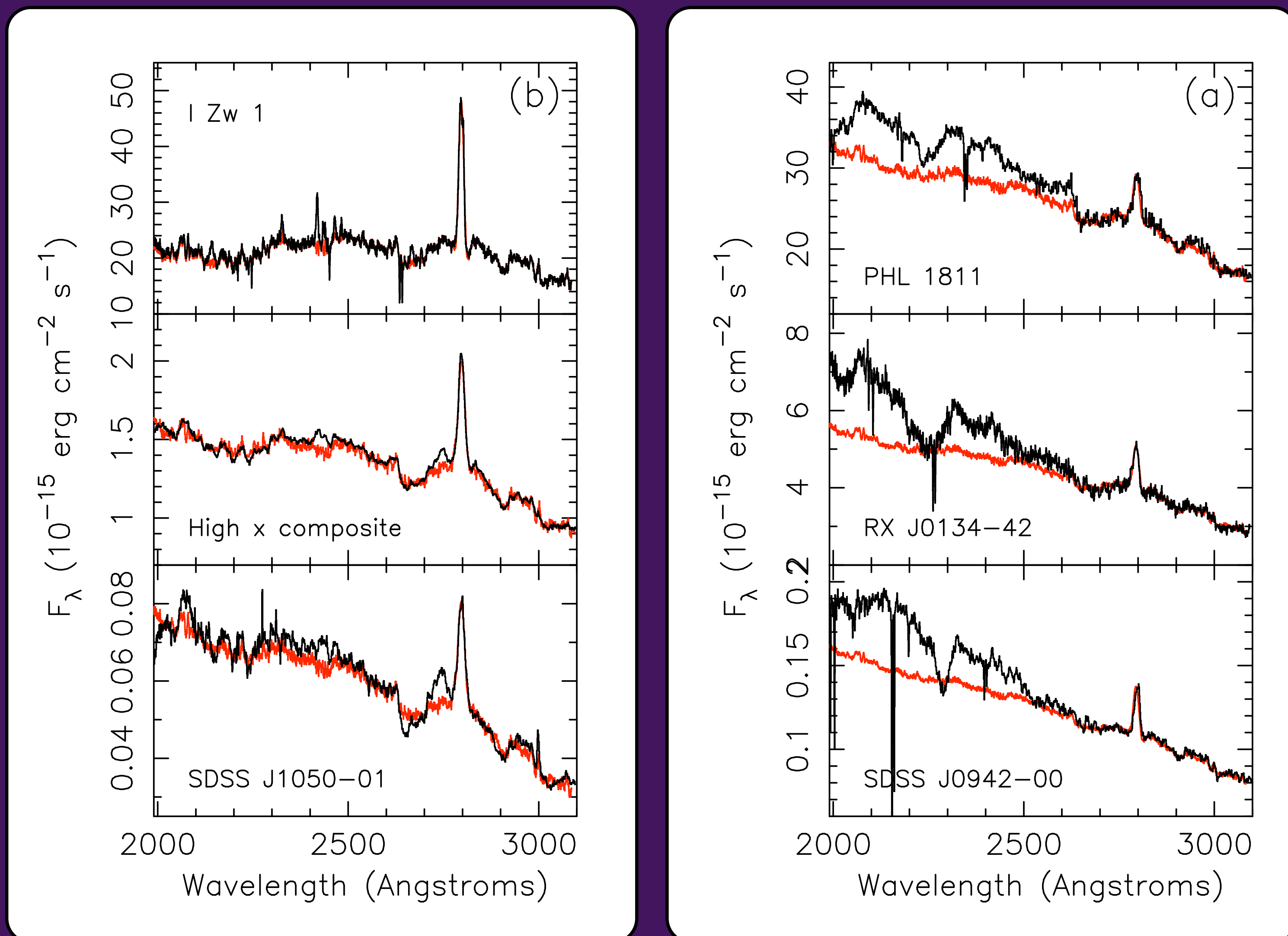
Wind-filtered Continuum

- Objects with blueshifted *high*-ionization lines have strong *low*-ionization lines (e.g., SiII, FeII; e.g. Wills et al. 1999).
- Implies emission very far from the black hole, unless....
- Filtering continuum through the wind softens it, leading to strong low-ionization lines.



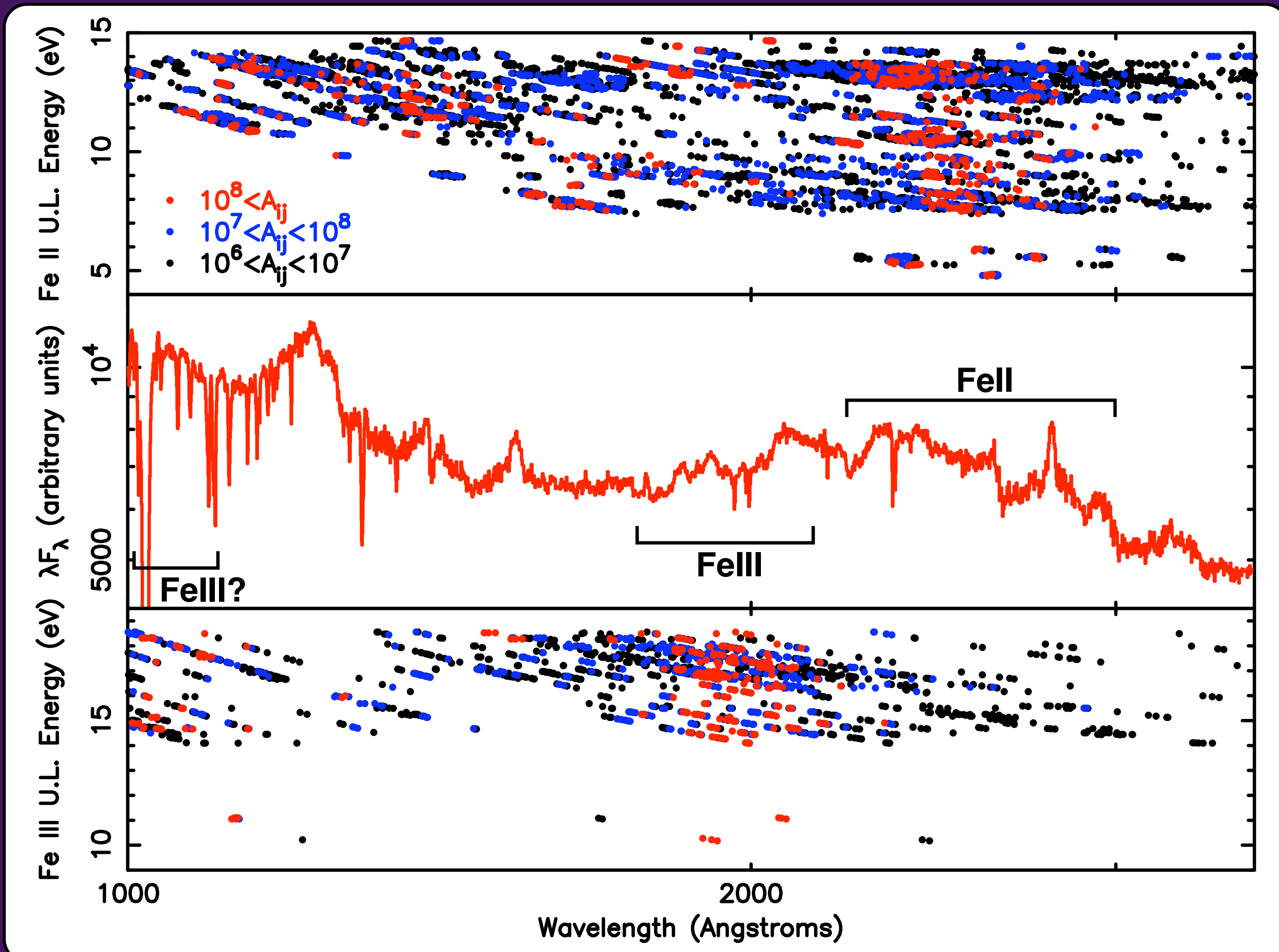
Leighly 2004

Near UV Observations of FeII



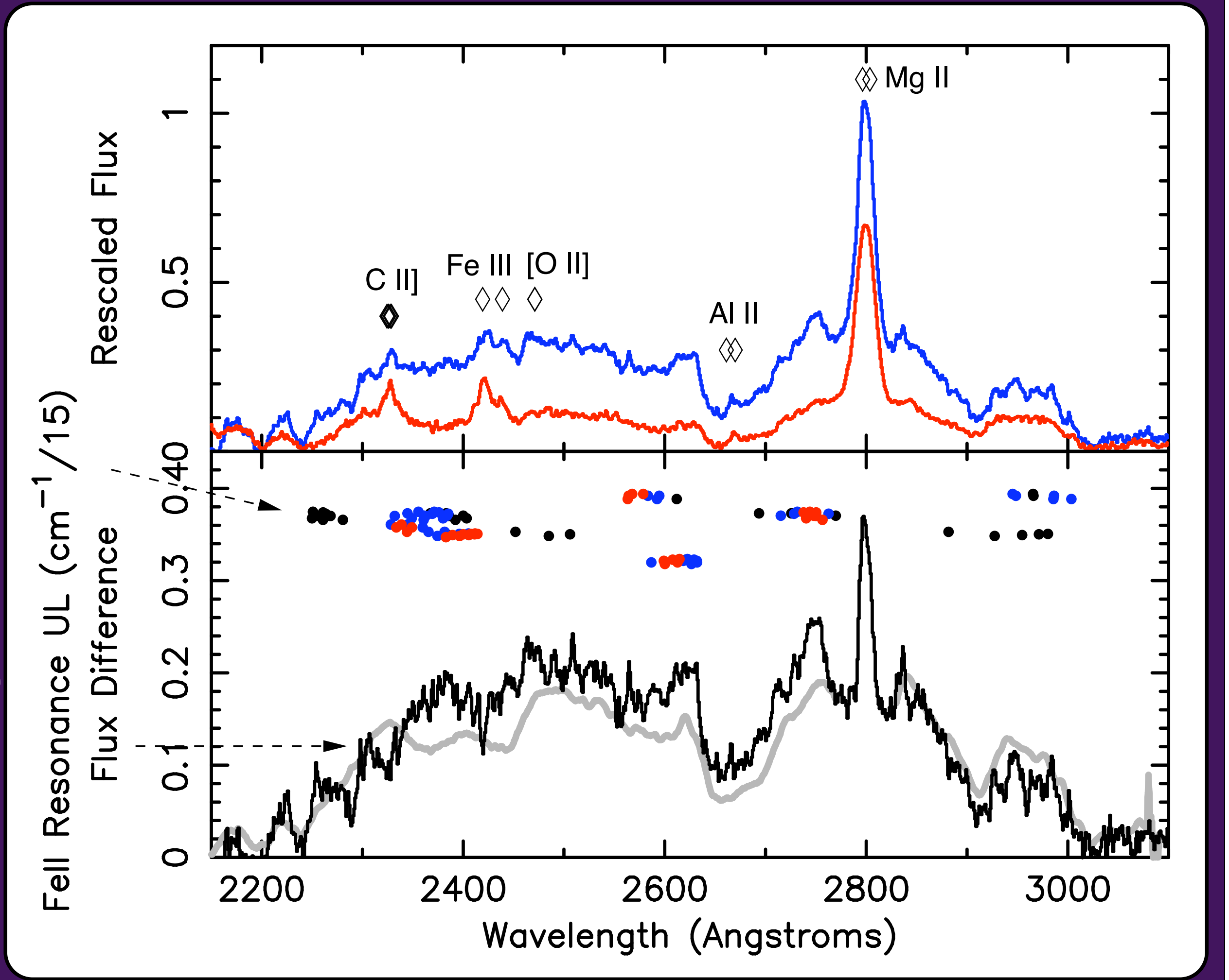
Leighly et al. 2006

Near UV Observations of FeII



Near UV Properties of Narrow-line Quasars from the SDSS

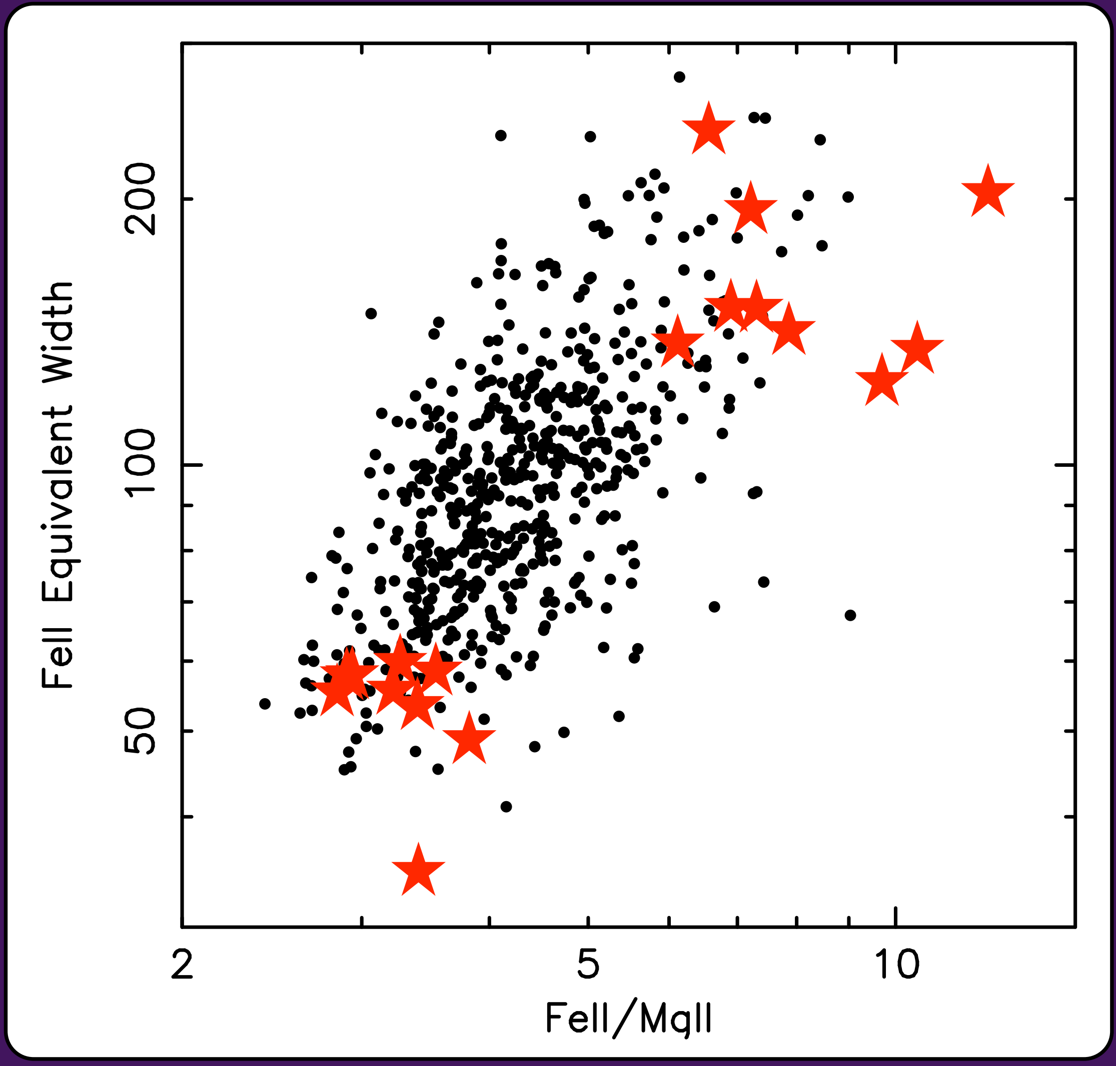
- Range of FeII/MgII ratios observed in the 1.2<z<1.8 sample of 903 objects.
- Composite spectra indicate possible differences in excitation.



Leighly & Moore 2006

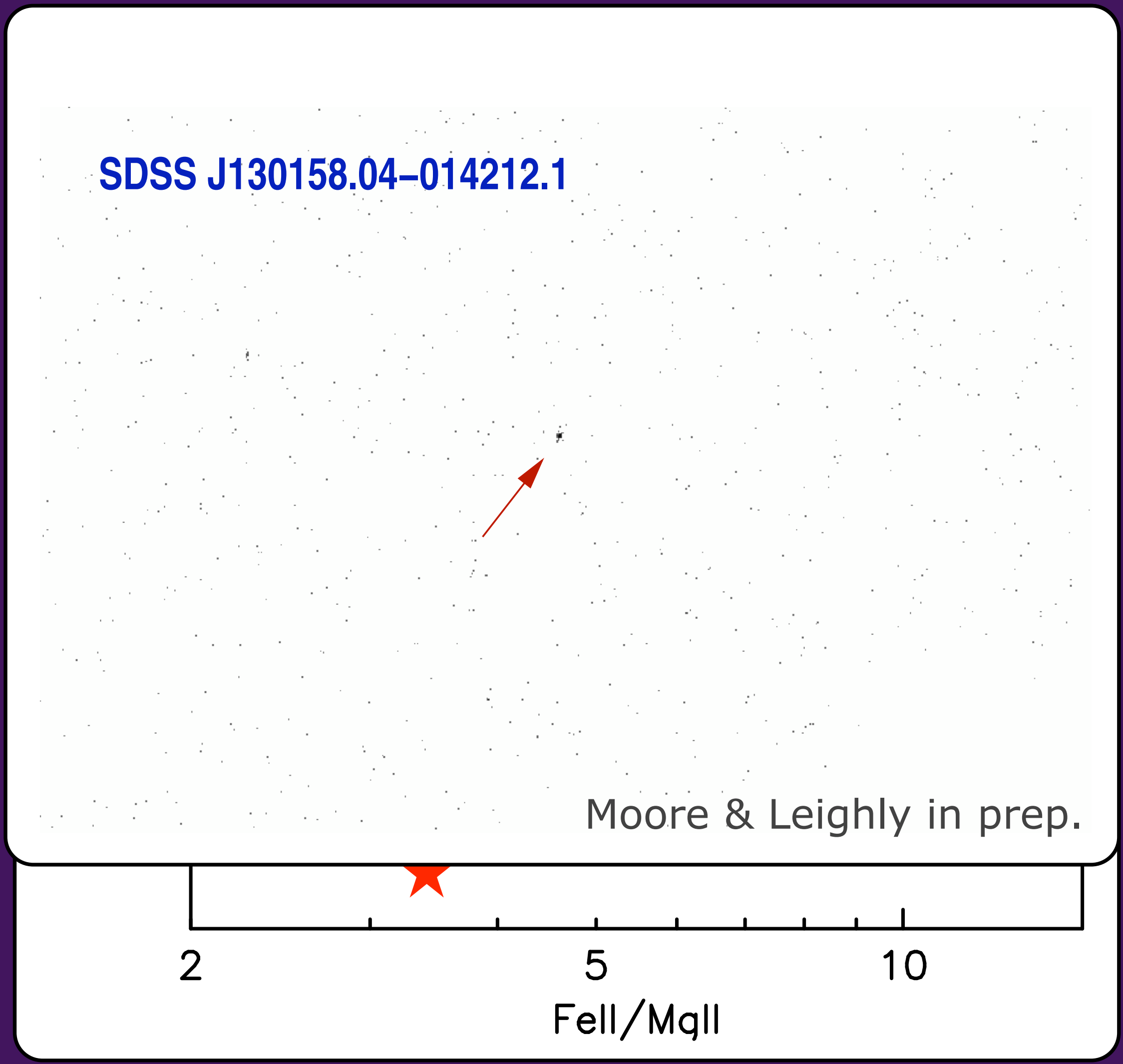
Chandra Observations

- PHL 1811 has strong FeII emission; perhaps strong FeII is generally associated with weak X-rays.
- We chose 6 high and 6 low FeII/MgII objects to observe with *Chandra*.
- Observations and analysis are underway.



Chandra Observations

- PHL 1811 has strong FeII emission; perhaps strong FeII is generally associated with weak X-rays.
- We chose 6 high and 6 low FeII/MgII objects to observe with *Chandra*.
- Observations and analysis are underway.

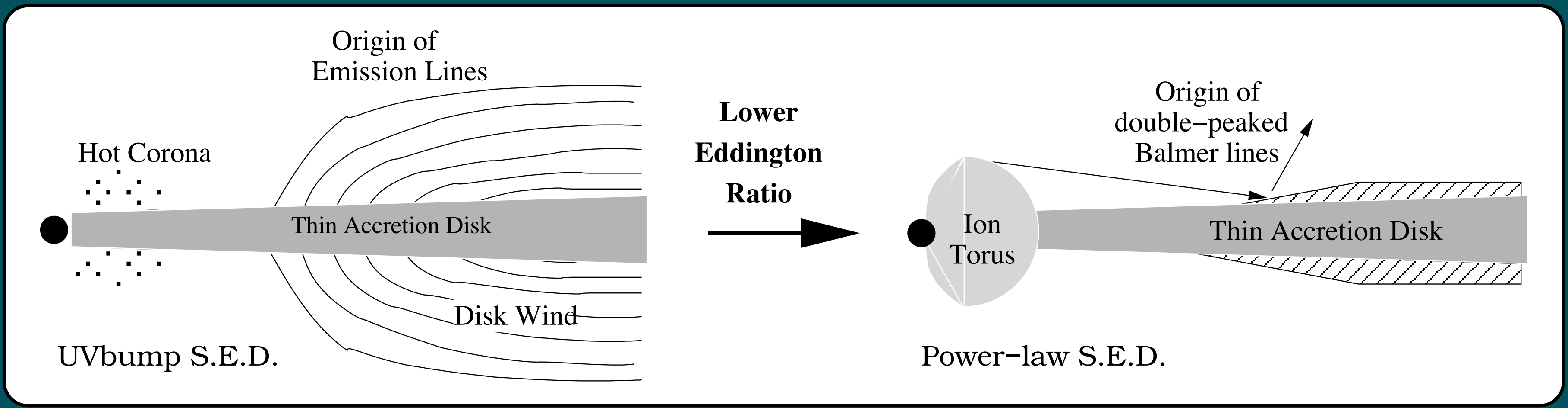


Is that all there is?

- Is a range of SED sufficient to explain full range of emission-line kinematic behavior?
- Probably not - and it is not necessary either - because the SED reflects BH mass and accretion rate, which may also determine emission geometry.

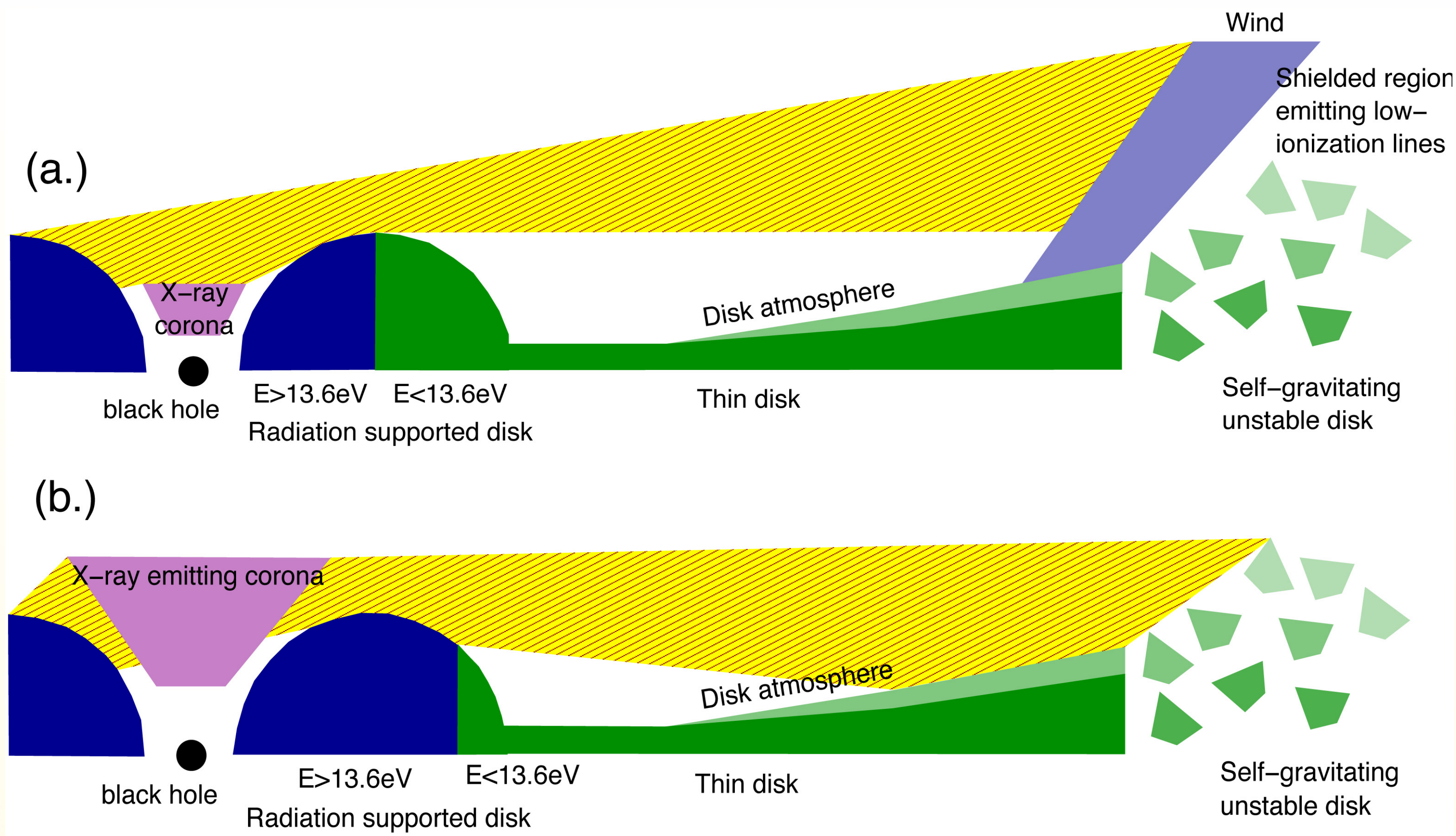
Double-peaked Emission-Line Objects

- Double-peaked BLRGs have flat α_{ox}'s, no blue bump, broad double-peaked low-ionization lines, narrow high-ionization lines (e.g., Mike Eracleous)
- "Anti-NLS1s"



Eracleous et al. 2004

Speculative Scenario



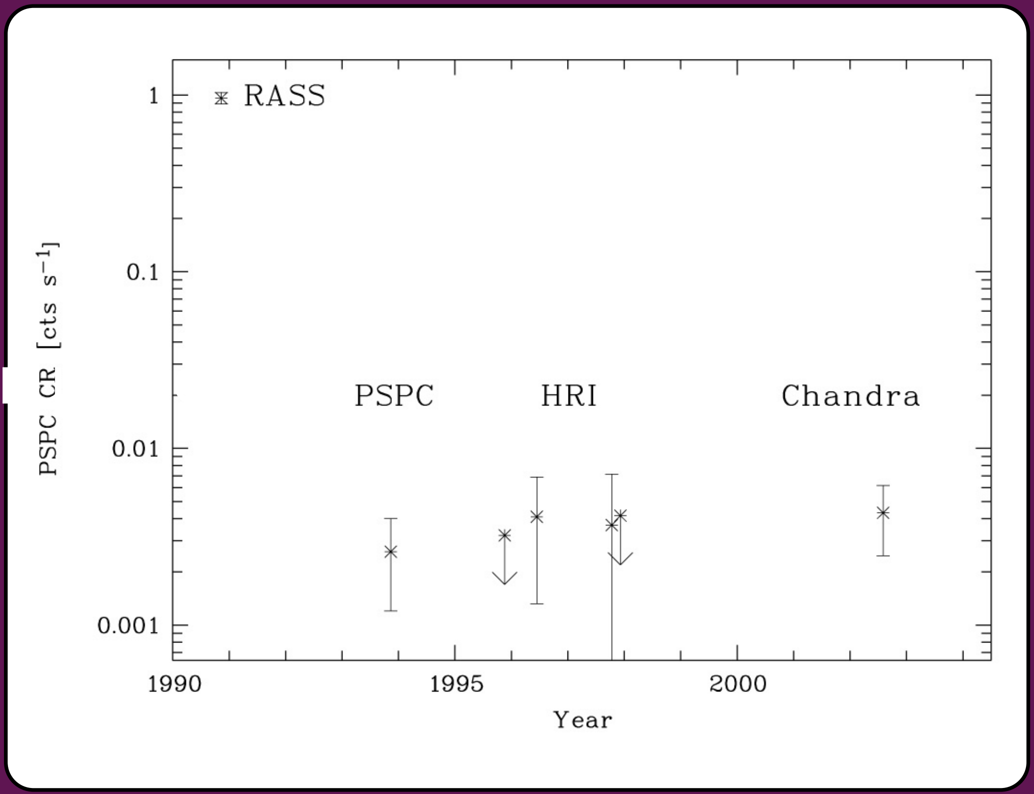
Leighly 2004

Considerations

- Wind location: 10,000 R_g - inferred from ionization parameter, column density, and "toy" dynamical model (F=ma) - interestingly close to Collin & Hure 2001 disk breakup radius.
- α_{ox} vs blueshift correlation => SED involved in wind.
- Conceptual difficulty with usual shielded wind - can't produce high-ionization emission lines that I observe.
- Mdot & M_{BH} are thought to determine SED to begin with, but still must protect wind from hard continuum.
- Do it geometrically - inner regions of moderate Mdot, M_{BH} disks may be radiation-pressure dominated => geometrically thick.

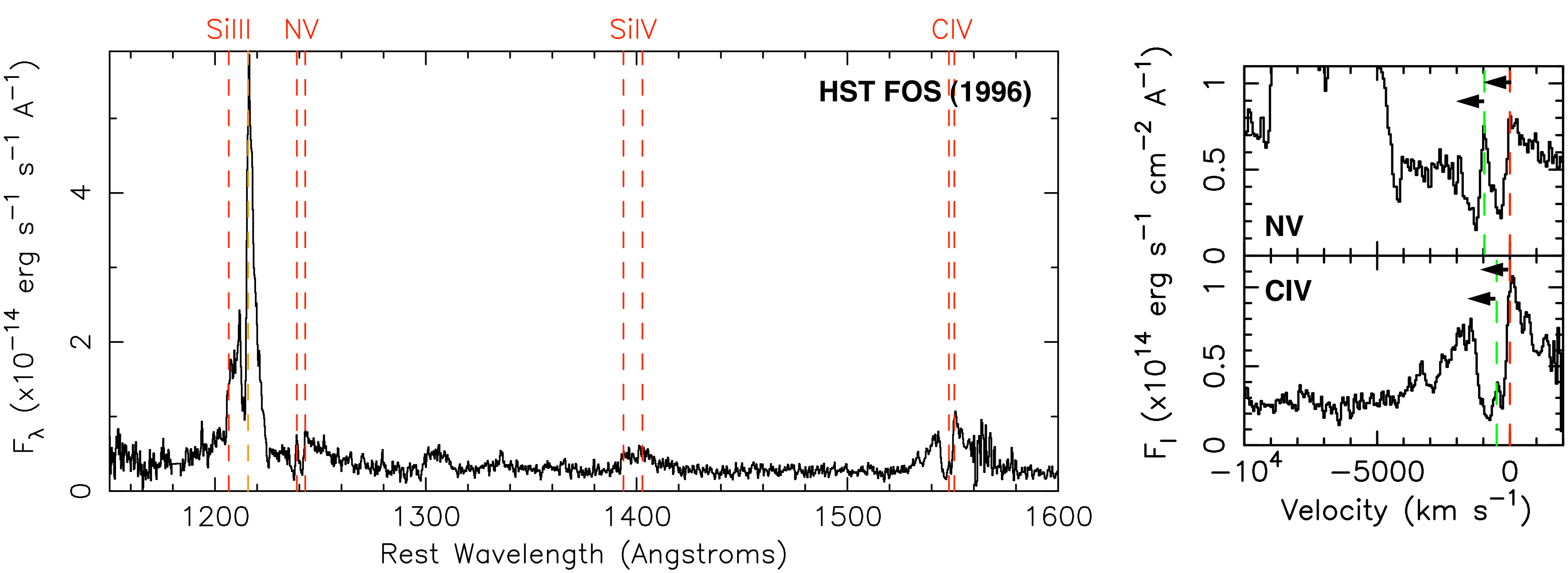
WPVS 007

- Low-luminosity NLS1(M_V=-19.7)
- Normal X-ray flux during RASS
- Practically turned off after RASS



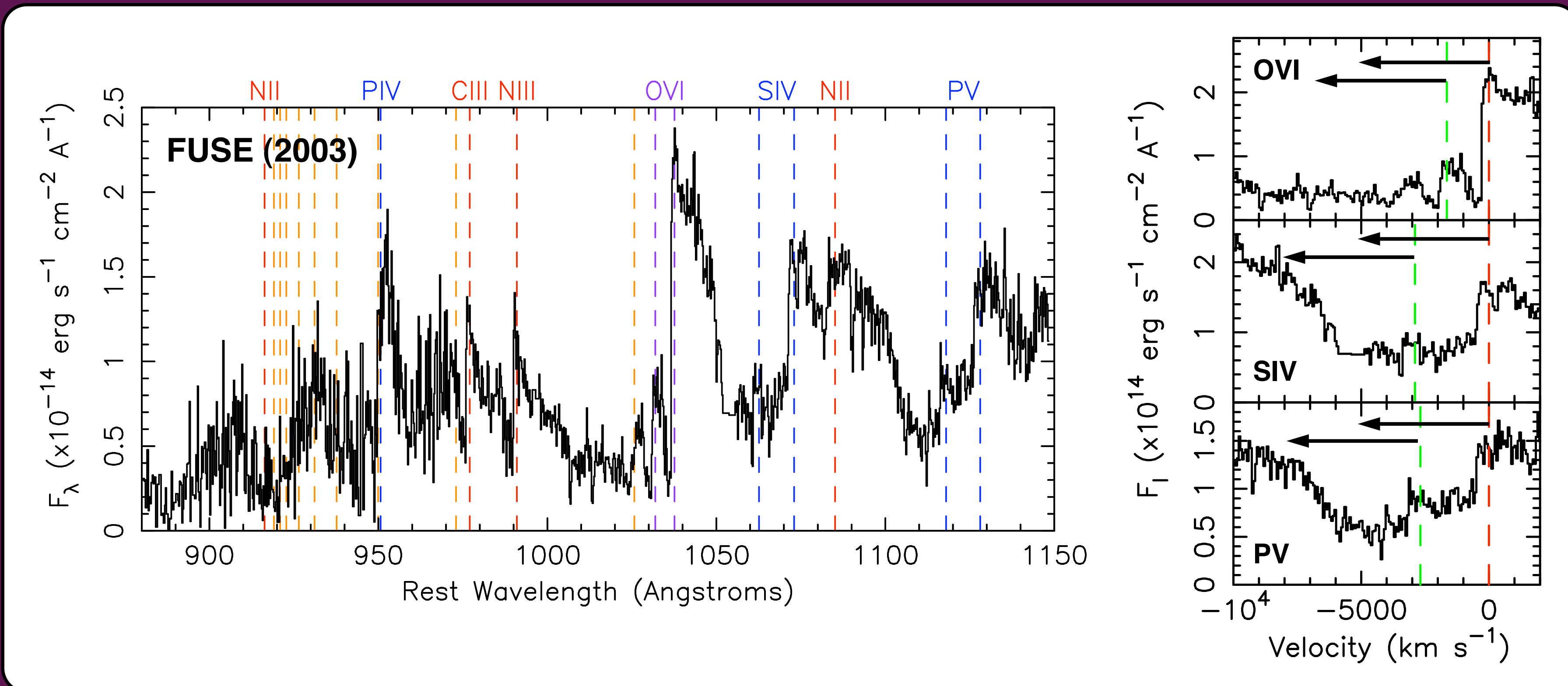
Grupe et al.

HST FOS Observation



- HST FOS spectrum from 1996 shows mini-BALs with v_{max}~900 km/s.

FUSE Observation



Leighly, Hamann, Grupe, Casebeer, in prep.

- FUSE Observation from 2003 shows the *emergence* of broad absorption lines with v_{max}~6000 km/s.

The Outflow in WPVS 007

- WPVS 007 is a low-luminosity (M_V=-19.7) narrow-line Seyfert 1. BAL flows in such low-luminosity objects have never been seen before.
- It has a estimated BH mass 1.2 x 10^6 M_{sun}, so small size scales permit significant variability on short times scales.
- Furthermore, became X-ray weak *before* BAL flow developed - X-ray absorption associated but not the same flow?

Summary

- In my opinion, AGN are not uniform in their outflow properties.
- The presence of an outflow is related to the spectral energy distribution.
- Geometrical differences may also be necessary.
- Spectral energy distribution and geometry is a function of the black hole mass and accretion rate - so that is what we are really looking at.
- WPVS 007 developed a BAL!