Fe II and Hβ Emission-lines of SDSS Quasars: New Clues to Geometry and Kinematics of Broad Line Region

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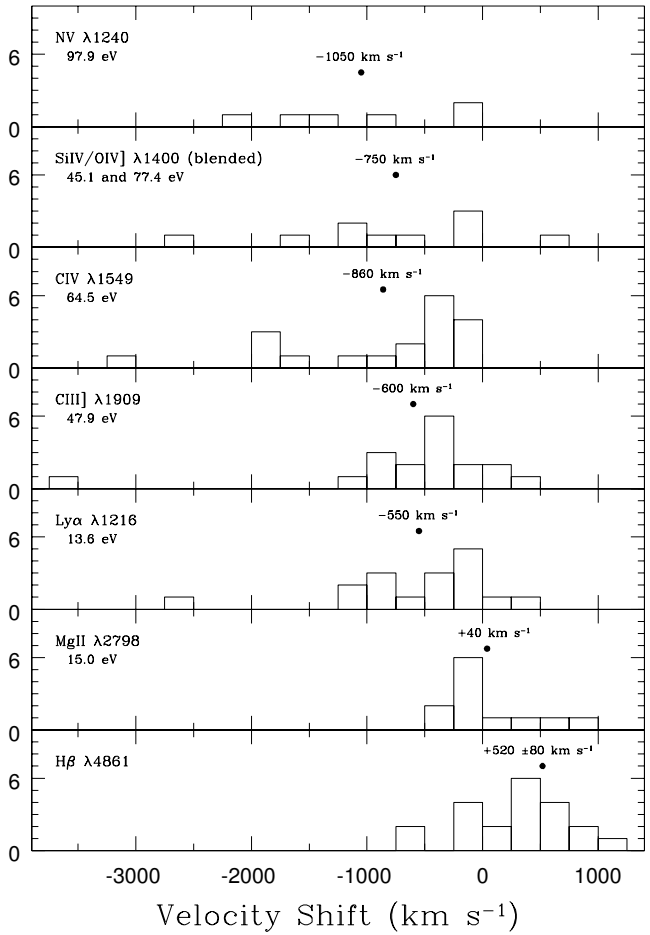
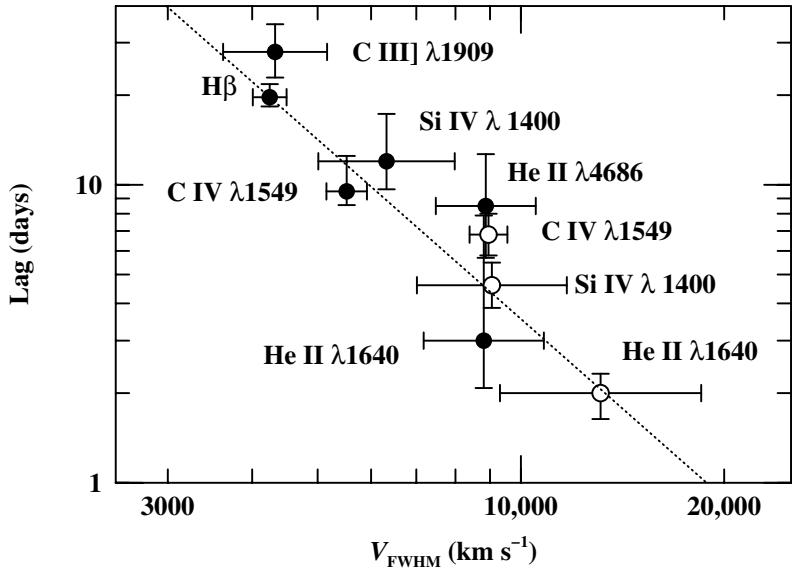
The stratification of the Broad Line Region



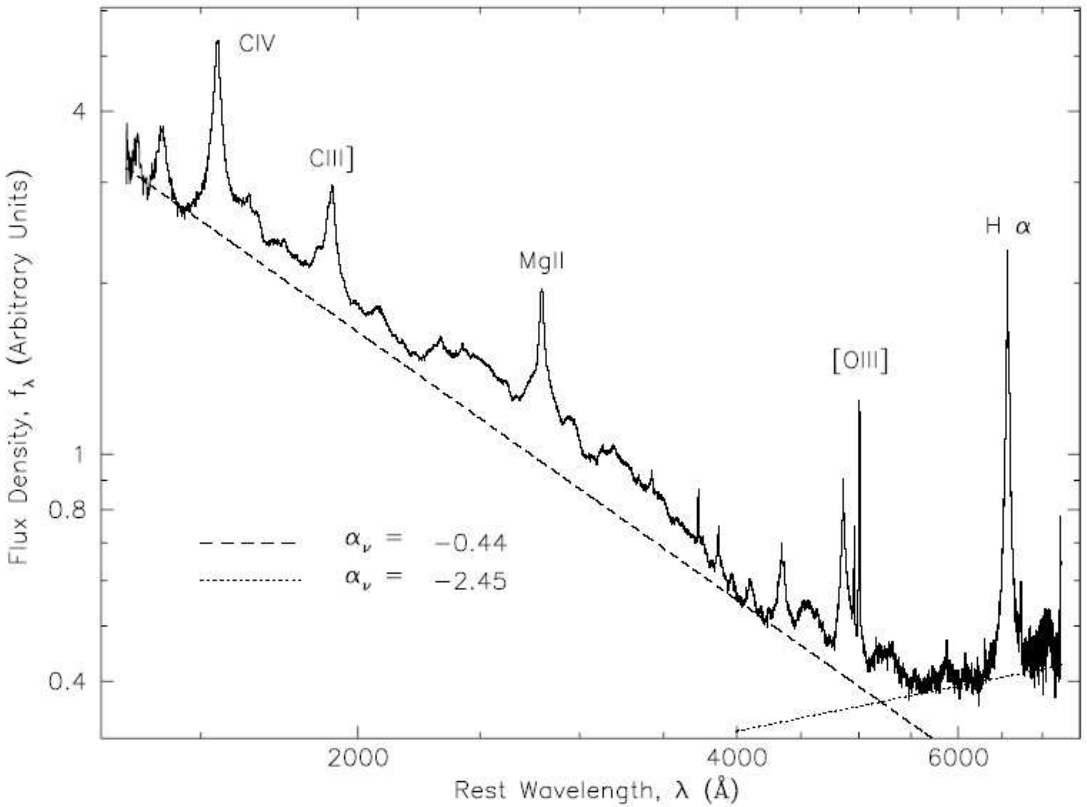
McIntosh, et al, 1999, ApJ, 517, L73

HIL region and LIL region



Peterson & Wandel, 1999, ApJ, 521, L95

Fe emission in optical and UV spectral



Vanden Berk et al. 2001, AJ, 122, 549

- Excitation mechanics? Origin?

Where is the Fe II emission region?

Similar widths and profiles of Fe II and Hβ:

Boroson & Green, 1992, ApJS, 80, 109

Further than Hβ emission region:

Matsuoka et al. 2007, O I and Ca II
Popović 2007, extensive Fe II emission region, intermediate width

The variability of Fe lines:

Vestergaard & Peterson 2005, NGC 5548
Wang et el. 2005, NGC 4051

- Low amplitude of variability and long response timescale

Sample selection

- SDSS DR5, $z < 0.8$, 14918 Type I Quasars (Schneider et al. 2007, AJ, 134, 102)
- S/N > 10
- $\chi^2 < 4$
- $\mathrm{H}\beta_{\mathrm{BC}}$ FWHM error $< 10\%$ and [O III] peak shift error < 100 $\mathrm{km\ s^{-1}}$
- $\mathrm{EW_{Fe}} > 25$ Å

4480 quasars

The overview of spectral fitting

1. Galactic extinction correction and redshift correction
2. Decomposition of the continuum spectrum
   - A single power law
   - Balmer continuum + high order Balmer lines
   - Fe emission lines
3. Emission-line fitting

- We ignore the host galaxy starlight component

Continuum decomposition

Continuum decomposition

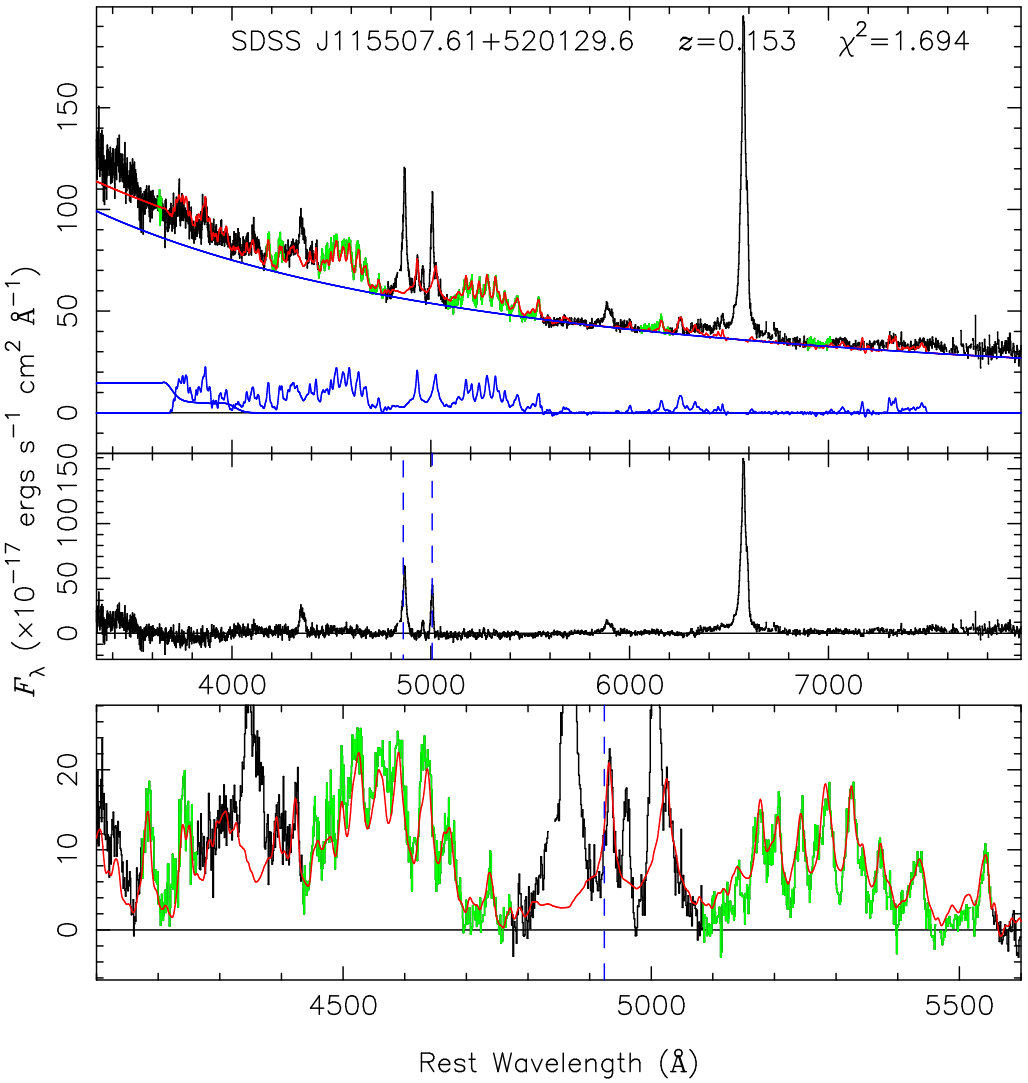
$$F_\lambda = F_\lambda^{\rm PL}(F_\lambda(5100), \alpha) + F_\lambda^{\rm BaC}(F_{\rm BE}, \tau_{\rm BE}) + F_\lambda^{\rm Fe}(F_{\rm Fe}, {\rm FWHM(Fe)}, V_{\rm Fe})$$

7 free parameters

Previous studies often:

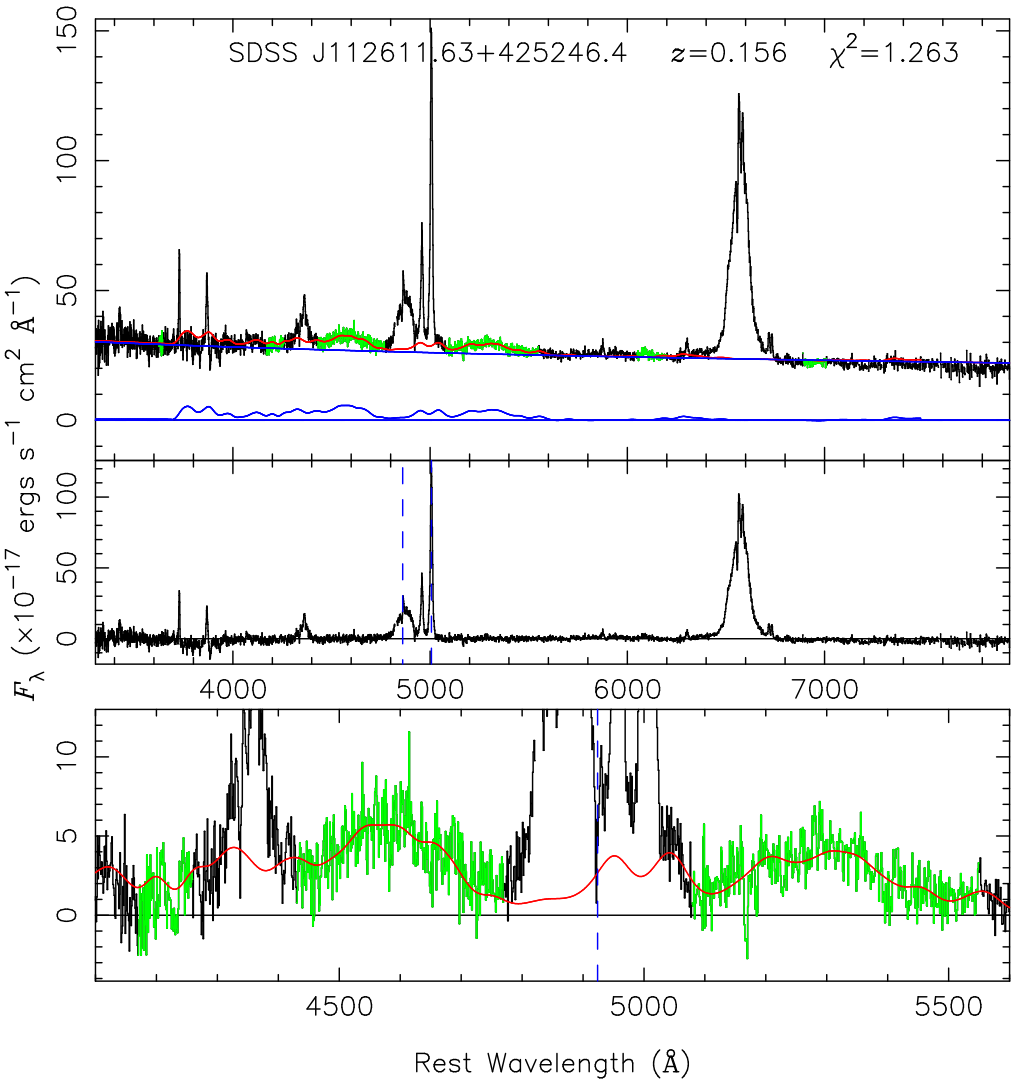
- fix $v_{\rm Fe}$ free $\rm FWHM_{Fe}$: e.g., *Boroson & Green 1992; Marziani et al. 1996; McLure & Jarvis 2002; Dietrich et al. 2003; Greene & Ho 2005; Woo et al. 2006*
- fix both $v_{\rm Fe}$ and $\rm FWHM_{Fe}$: e.g., *Netzer & Trakhtenbrot 2007; Salviander et al. 2007*

Examples of continuum decomposition



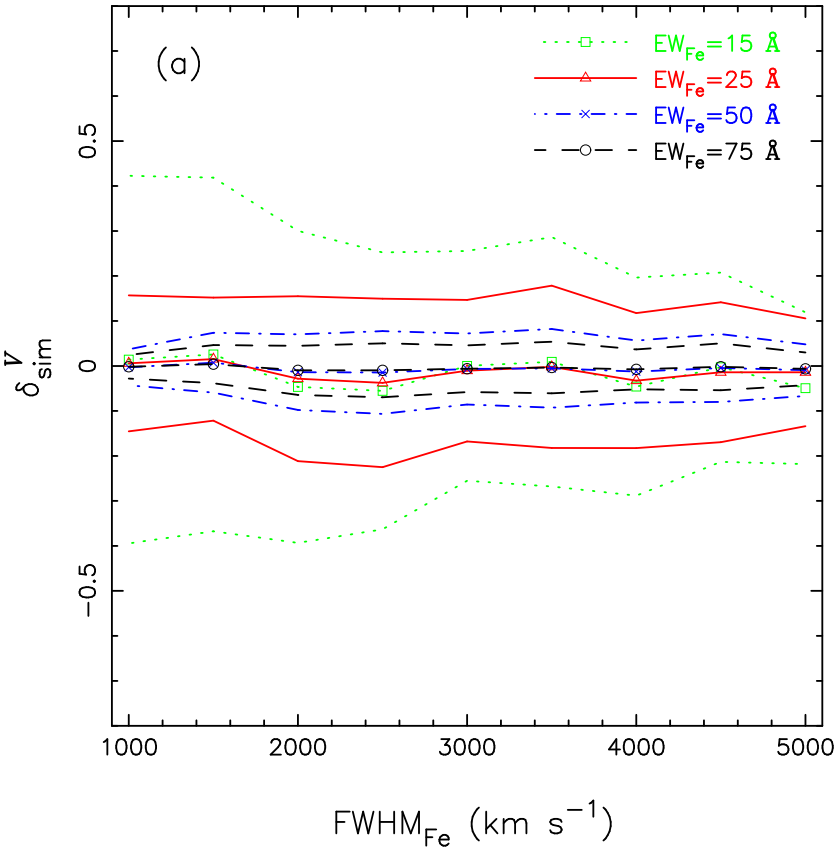
457 ± 14 km s^{-1}

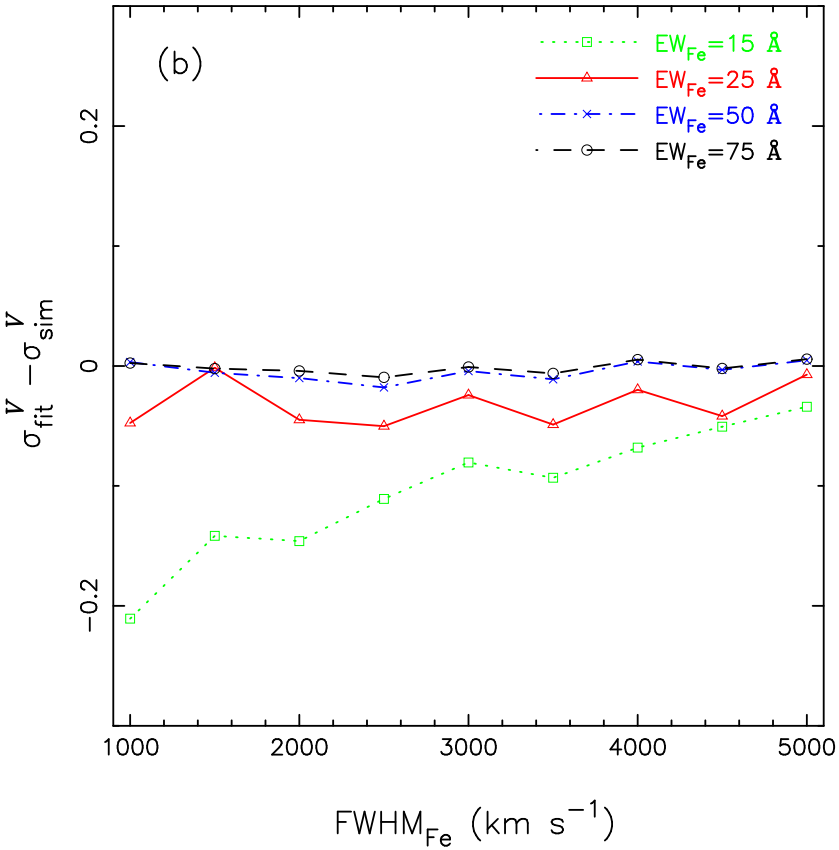
Examples of continuum decomposition



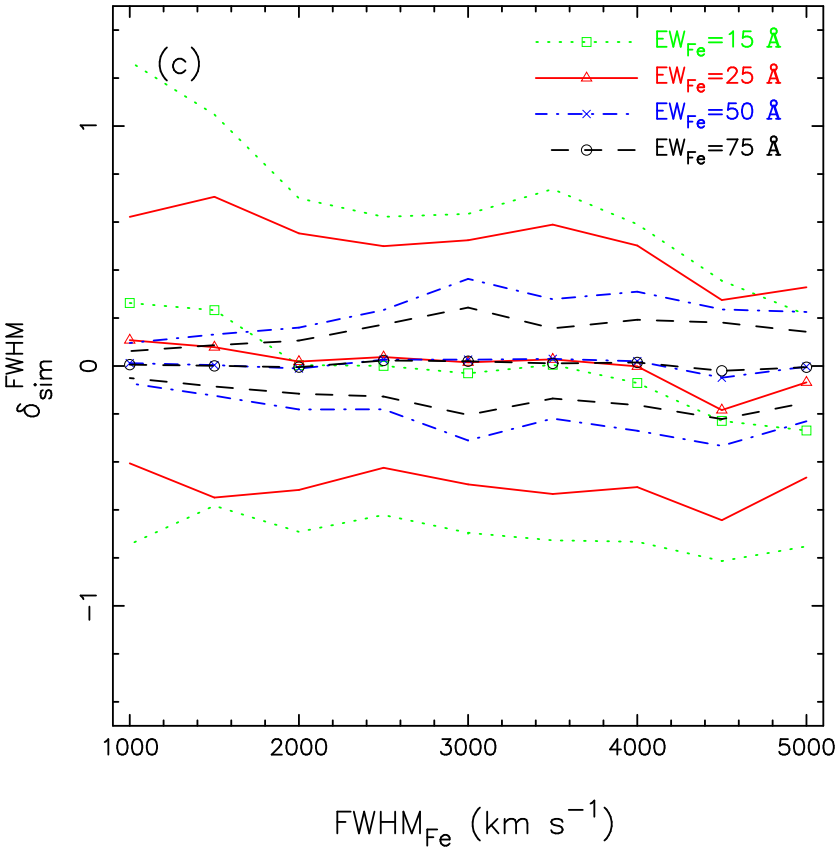
1692 ± 119 km s^{-1}

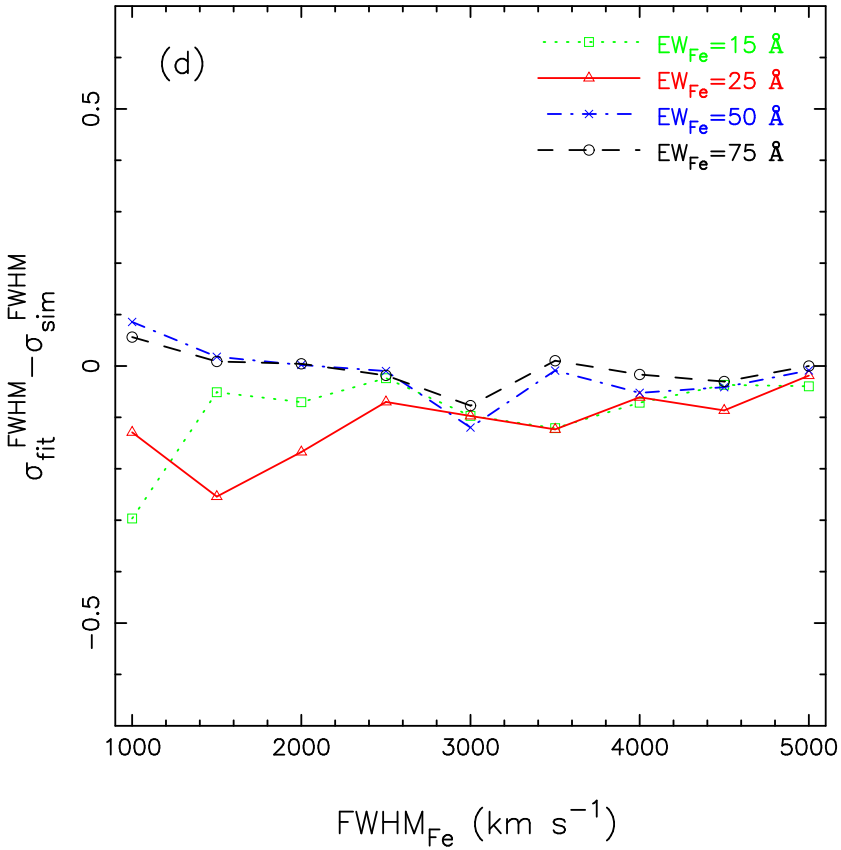
Monte-Carlo simulation: shift





Monte-Carlo simulation: width





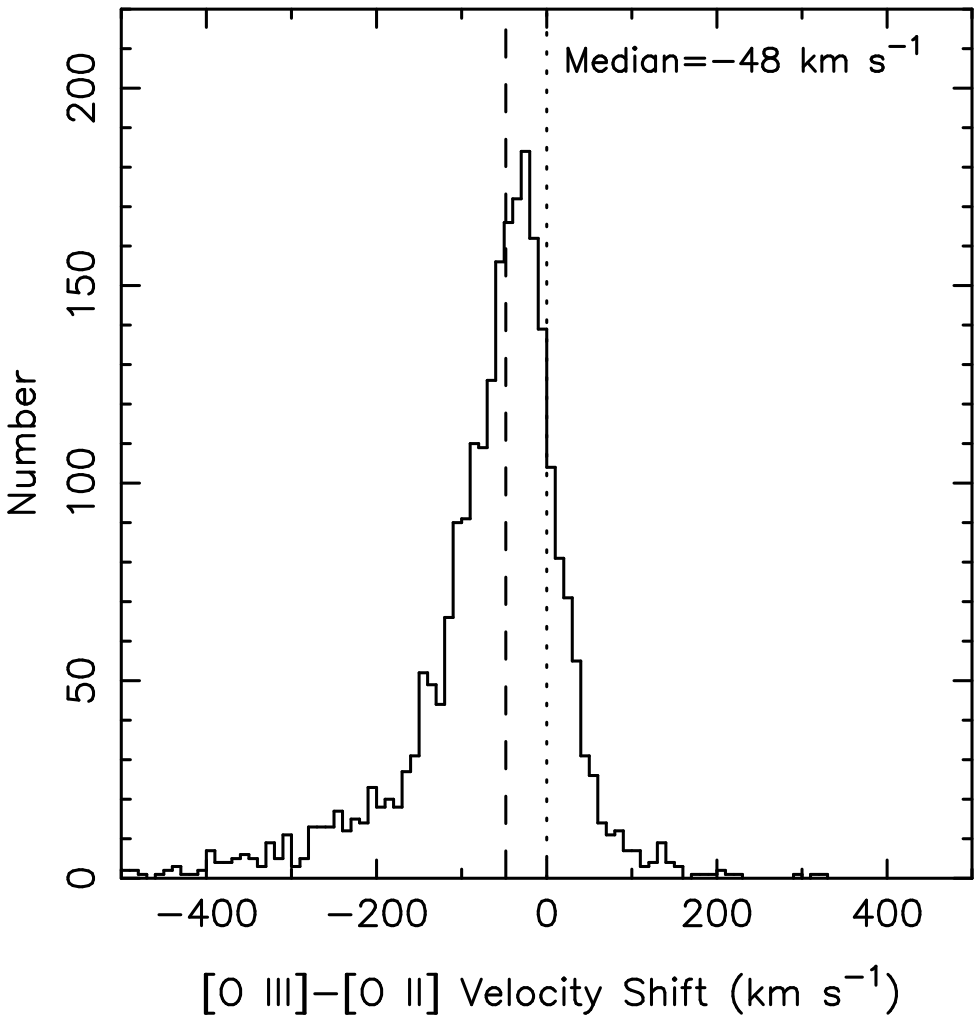
Comparison with conventional methods

- F-test: compare with
  - A, fix $v_{\rm Fe}$ free $\rm FWHM_{Fe}$: 58% sources have significance more than 3σ
  - B, fix both $v_{\rm Fe}$ and $\rm FWHM_{Fe}$: 87%

Table: Effect of Fe Template-fitting Method on Other Parameters

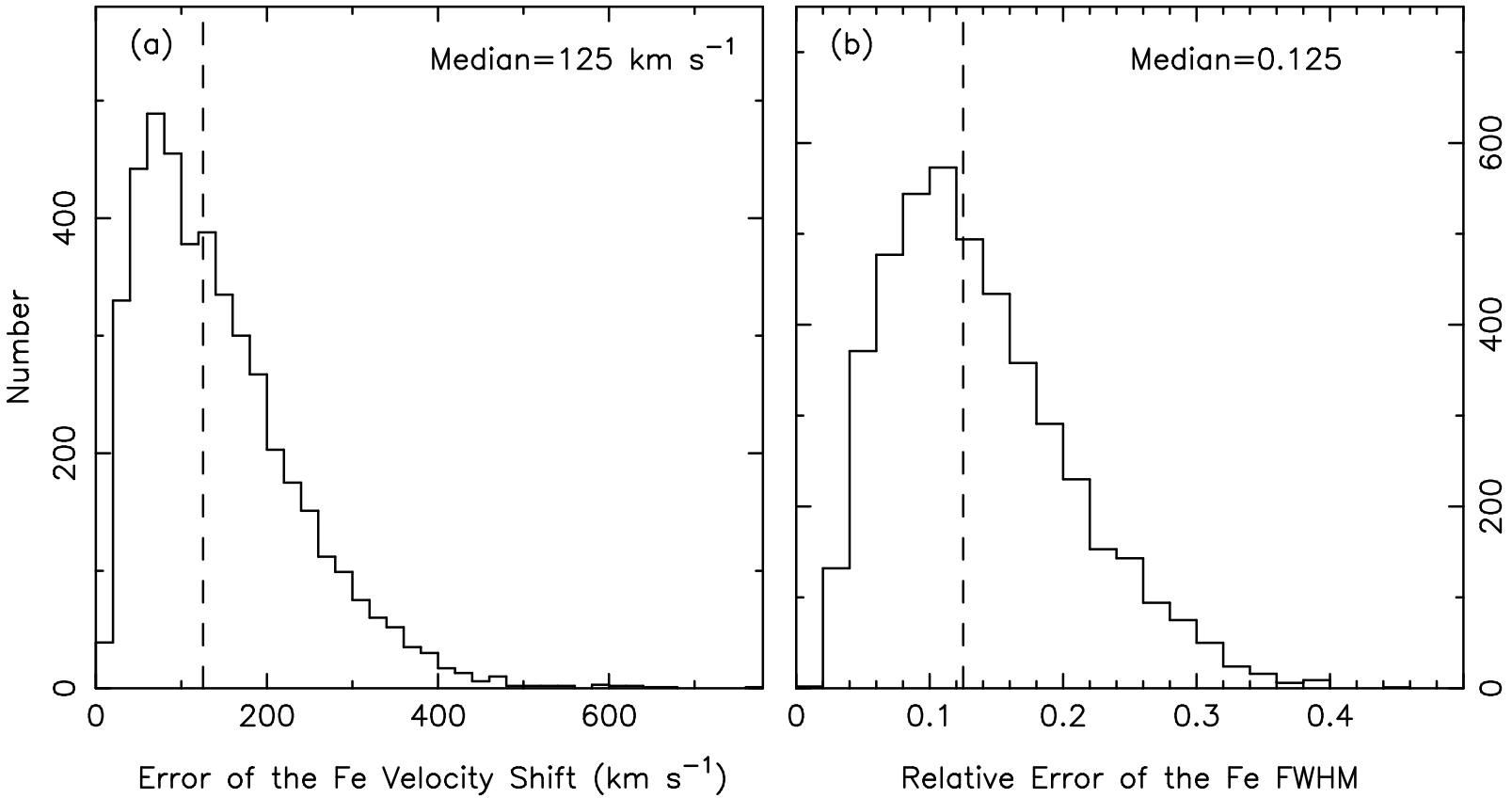
Model (1)	$L(\rm H\beta_{BC})$ (2)	$\rm FWHM(H\beta_{BC})$ (3)	$V_{\rm H\beta}$ (4)	$L_{\rm [O\ III]}$ (5)	$\rm FWHM_{[O\ III]}$ (6)	$V_{\rm [O\ III]}$ (7)
A	−2.30%(3.15%)	−1.58%(3.56%)	−23.2(37.4)	2.52%(40.7%)	0.51%(19.2%)	2.45(35.6)
B	−1.66%(3.25%)	1.24%(4.45%)	−2.36(57.9)	1.79%(51.9%)	0.51%(24.4%)	5.17(41.1)

Systemic redshift: using [O III]

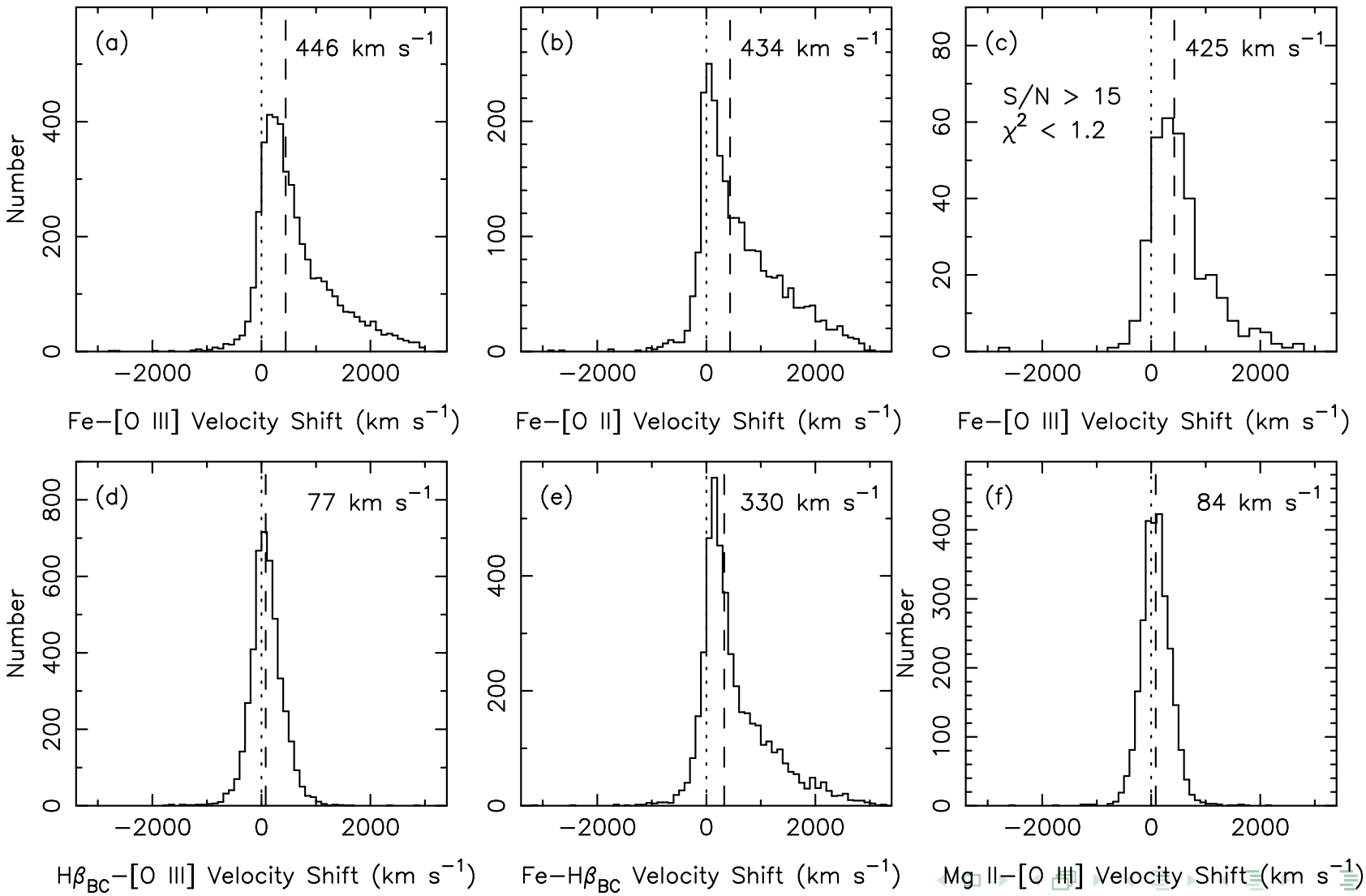


Consistent with
Boroson 2005:
Blueshifted [O III] emission

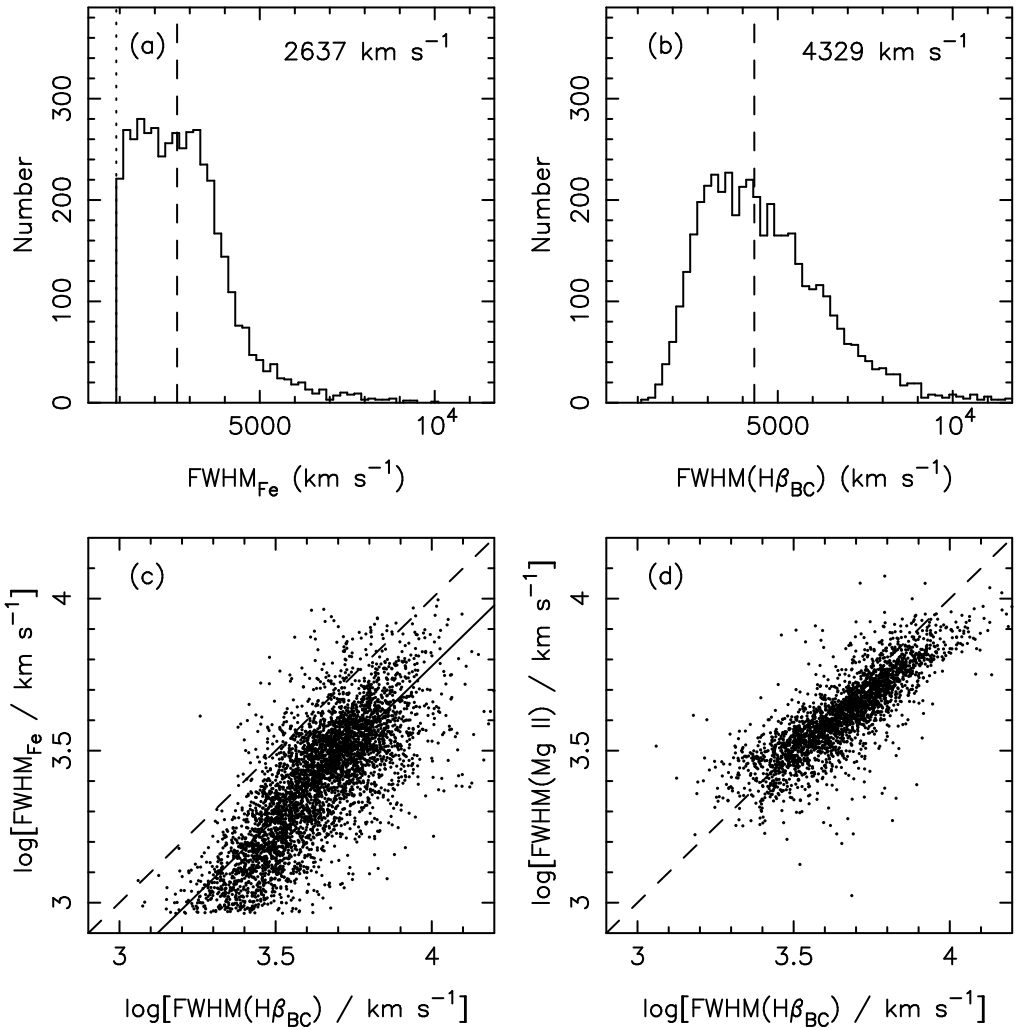
Error of the Fe II velocity shift and width



Distribution of Fe II emission shifts

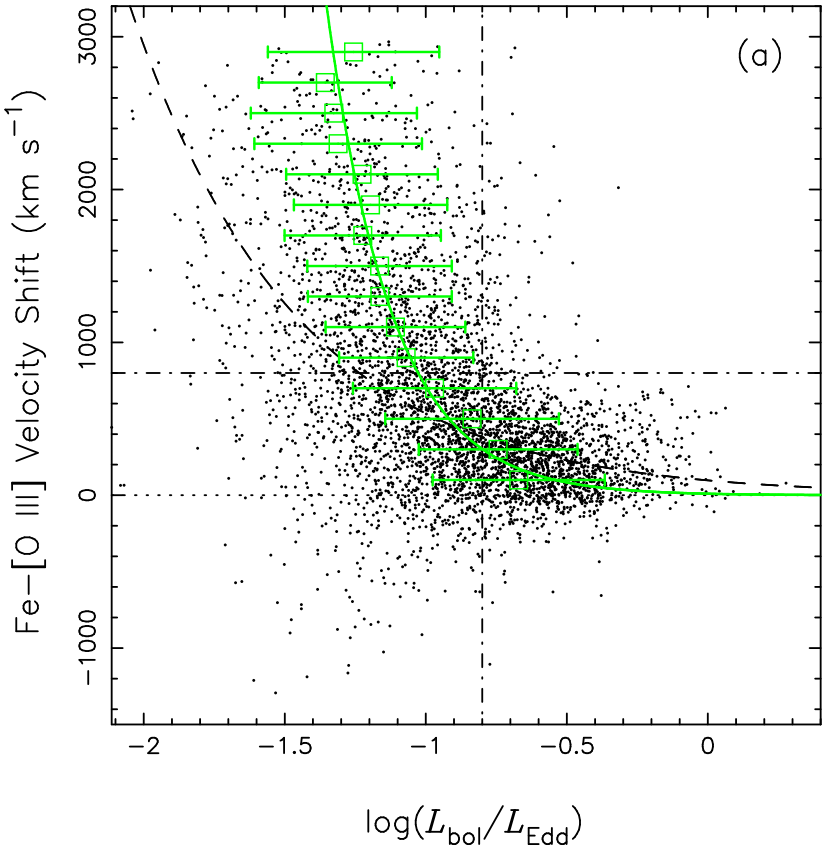


Fe II emission FWHM

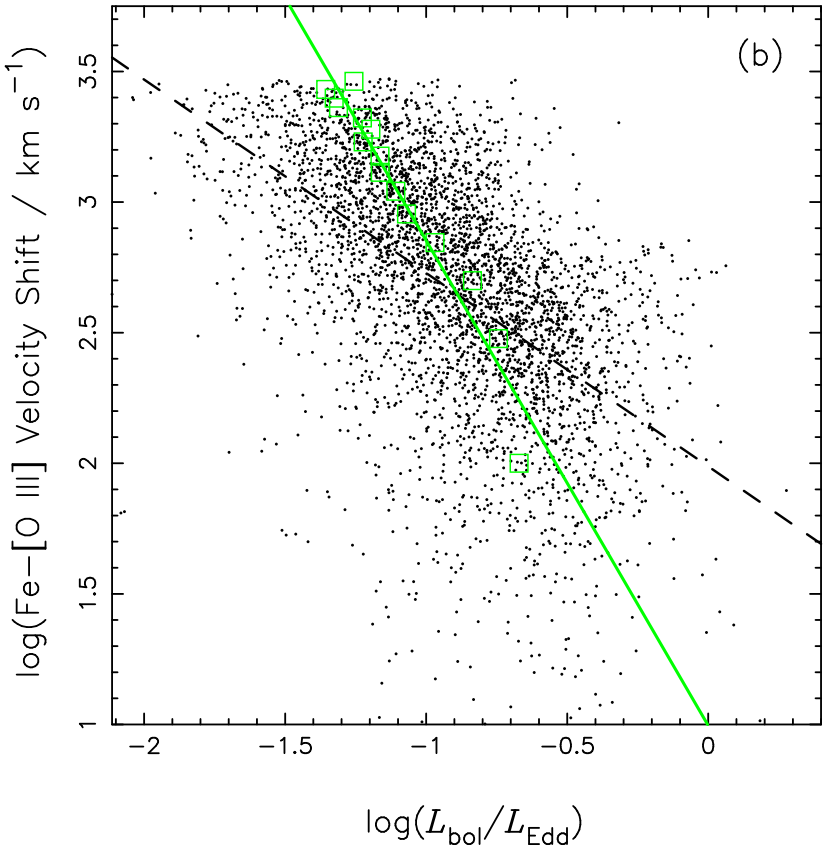


The physical driver of $v_{\rm Fe}$

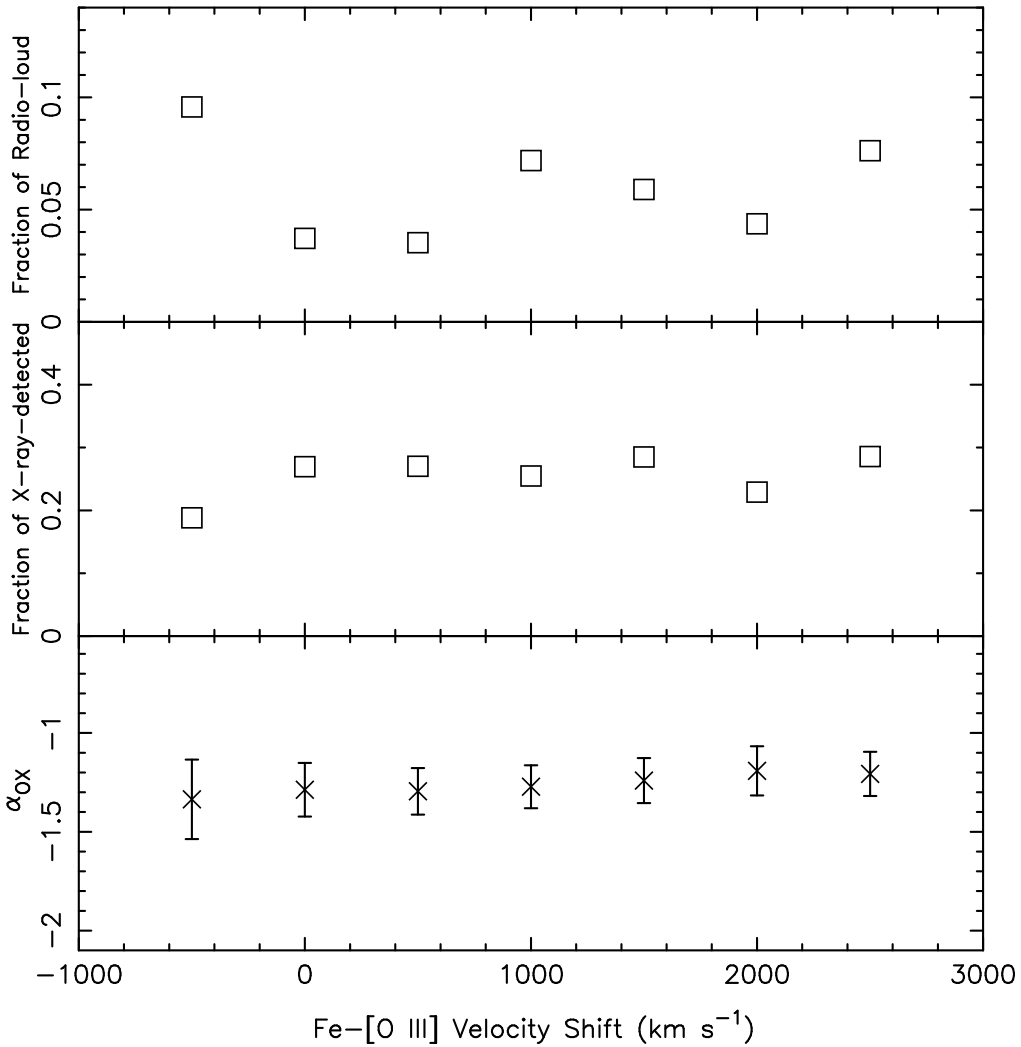
$v_{\rm Fe}$ vs. $\log(L_{\rm bol}/L_{\rm Edd})$



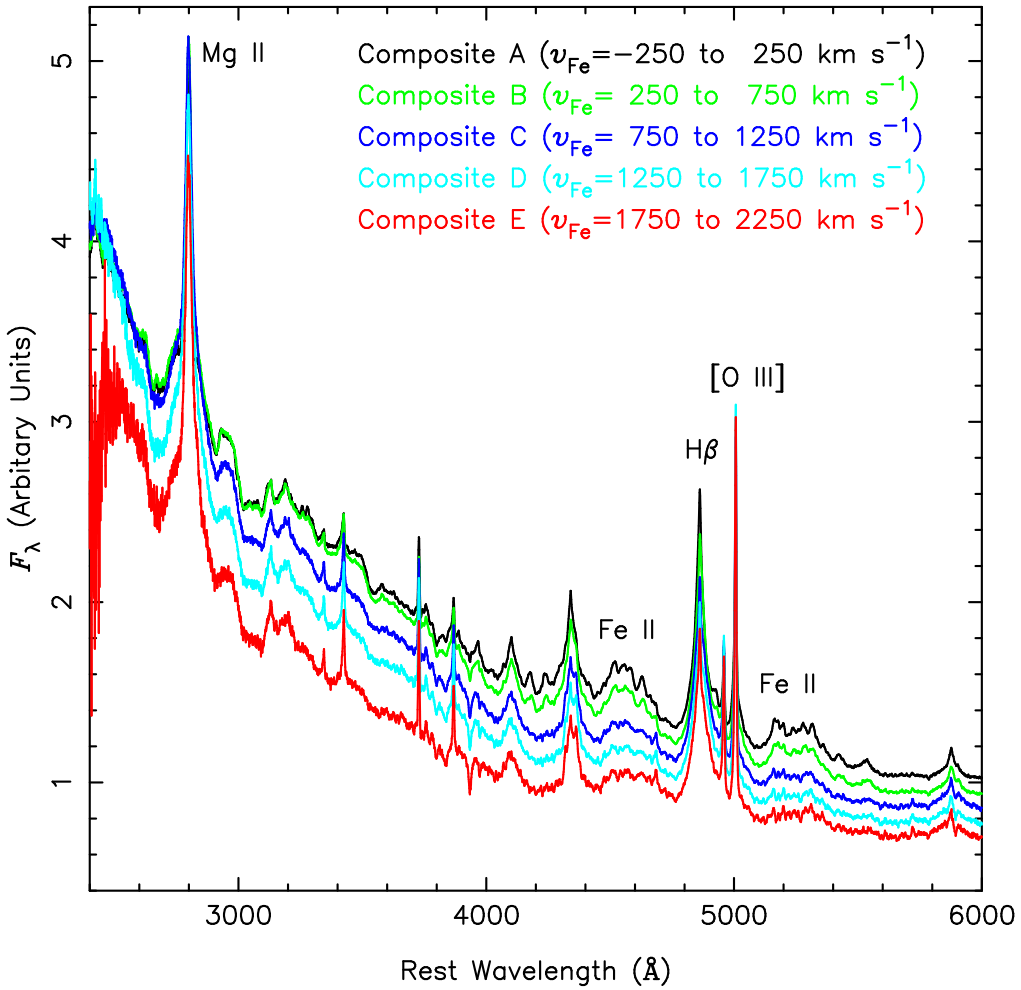
$\log(v_{\rm Fe})$ vs. $\log(L_{\rm bol}/L_{\rm Edd})$



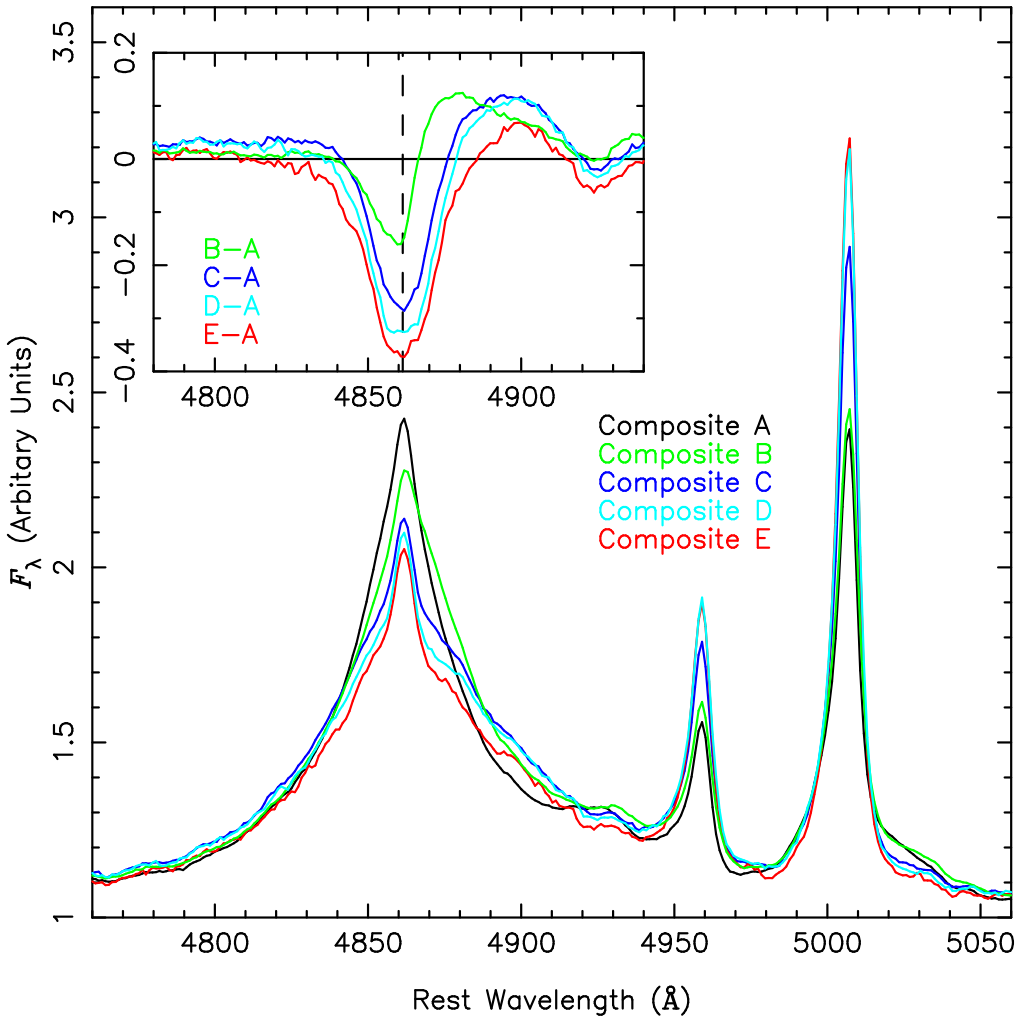
Correlations with radio and X-ray properties



Composite spectra



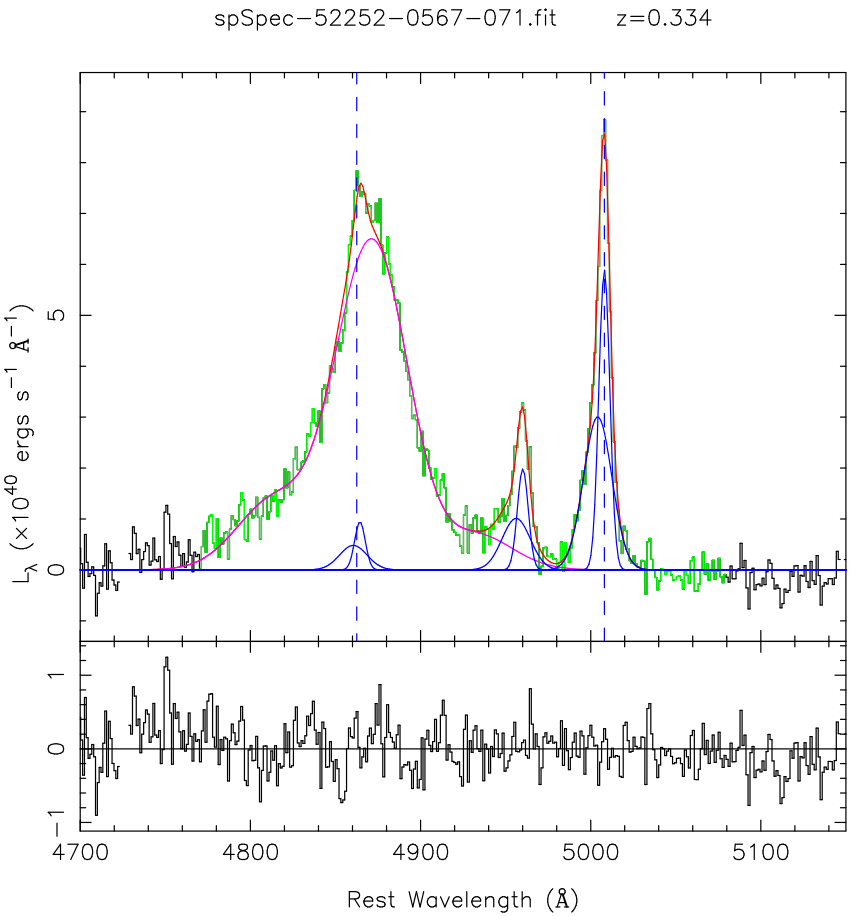
Composite spectra

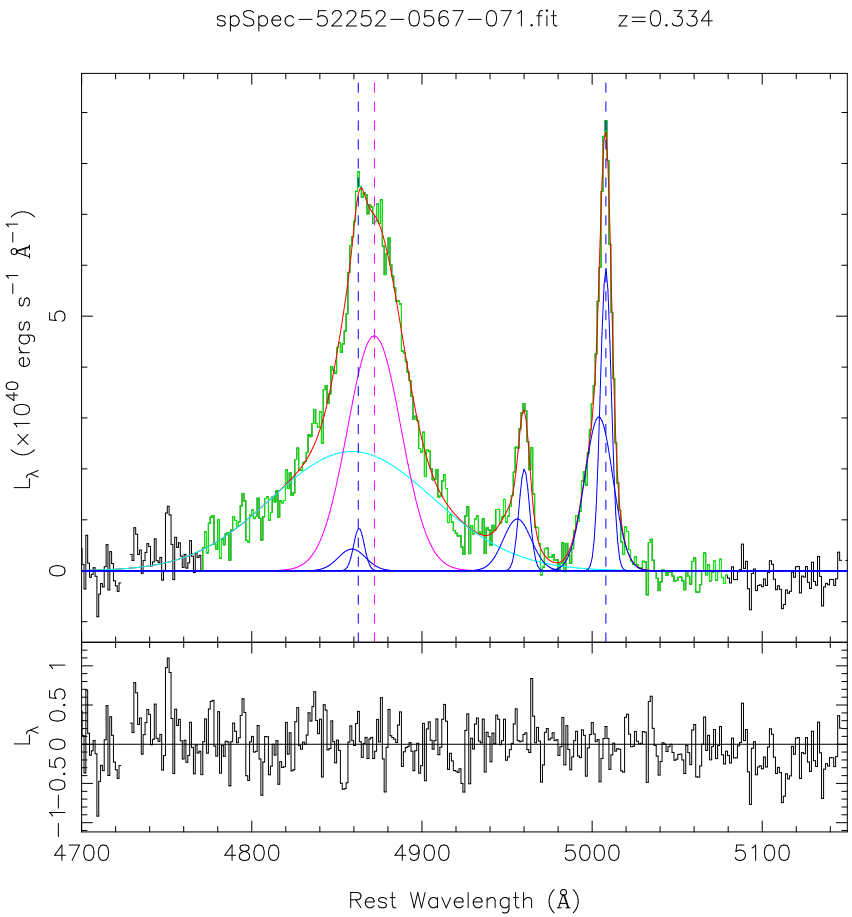


Hβ profile

- Broad line AGN: one Gaussian is not good.
  - Two Gaussian: e.g. *Netzer & Trakhtenbort 2007*
  - Gauss-Hermite: e.g. *Salviander et al. 2007*
- NLS1:
  - Lorentzian
  - Lorentzian + very broad Gaussian component: e.g. *Véron-Cetty et al. 2004*
  - Two Gaussian: e.g. *Mullaney & Ward 2008*

Examples


spSpec−52252−0567−071.fit z=0.334
L_λ ($\times 10^{40}$ ergs s^{-1} Å^{-1})
Rest Wavelength (Å)

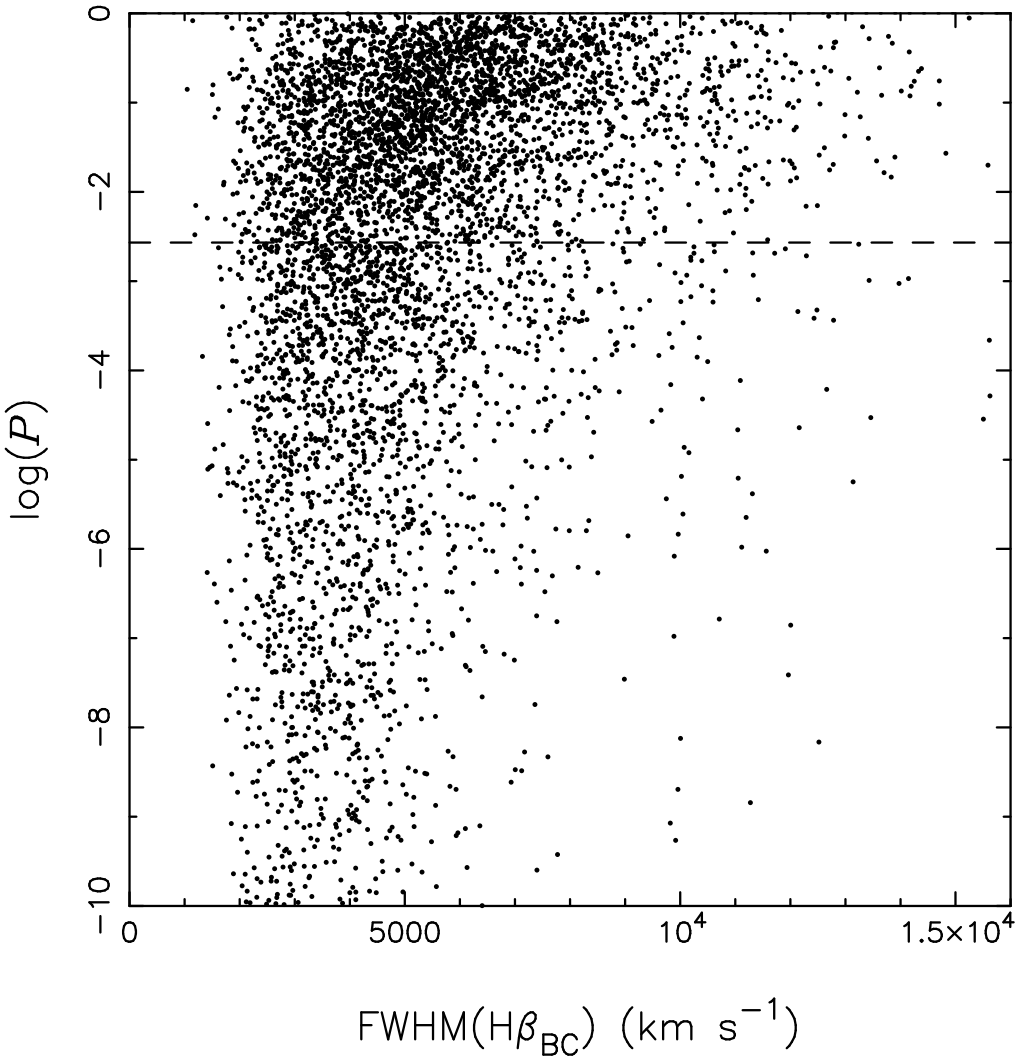

spSpec−52252−0567−071.fit z=0.334
L_λ ($\times 10^{40}$ ergs s^{-1} Å^{-1})
Rest Wavelength (Å)

Hβ profile fitting

- The narrow component is forced to have the same profile as [O III].

- For the conventional broad component:
  - Using only one Gaussian: $\mathrm{H}\beta_{\mathrm{BC}}$
  - Using two Gaussian: $\mathrm{H}\beta_{\mathrm{VBC}}$ + $\mathrm{H}\beta_{\mathrm{IC}}$

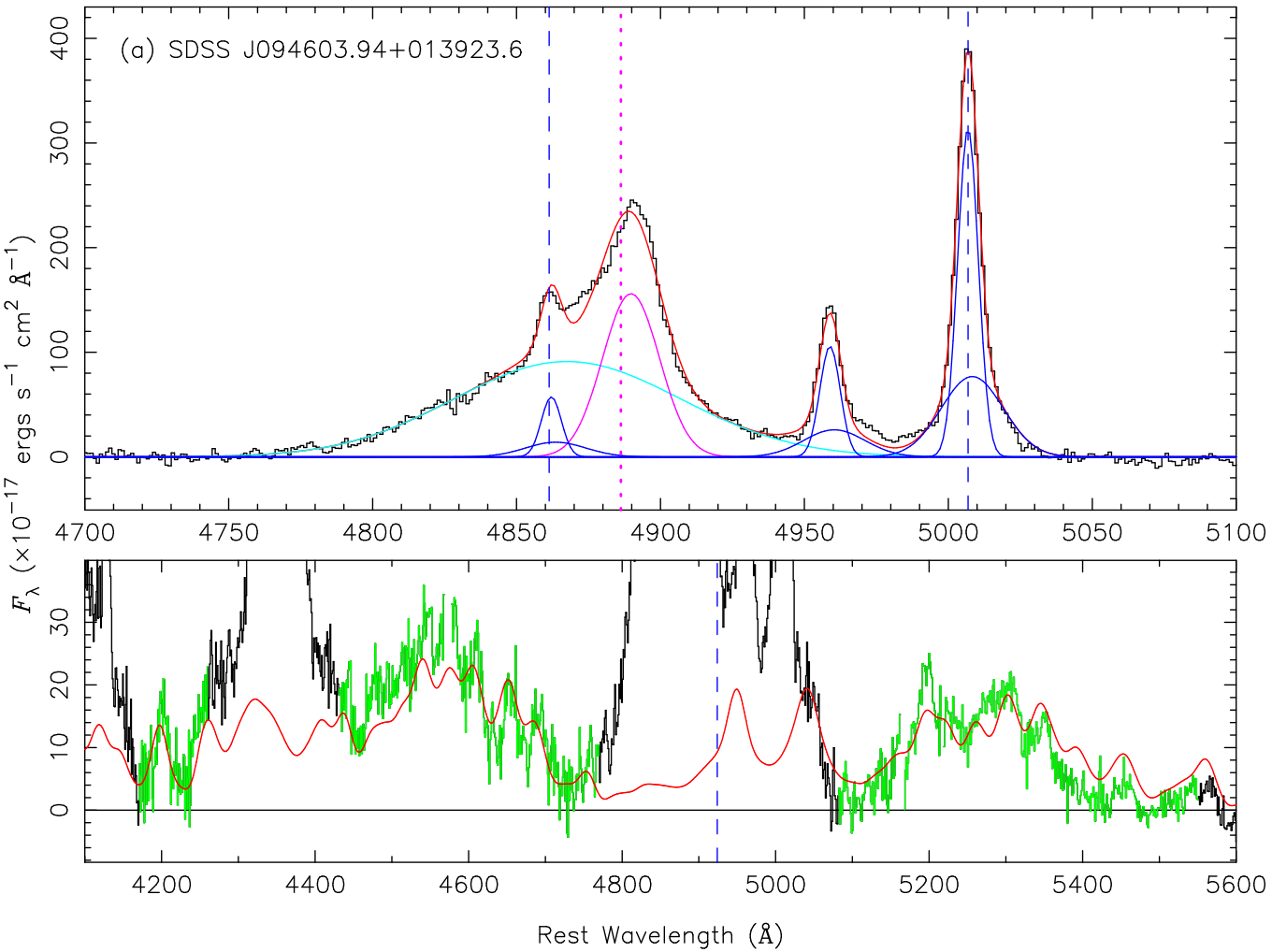
Hβ profile fitting



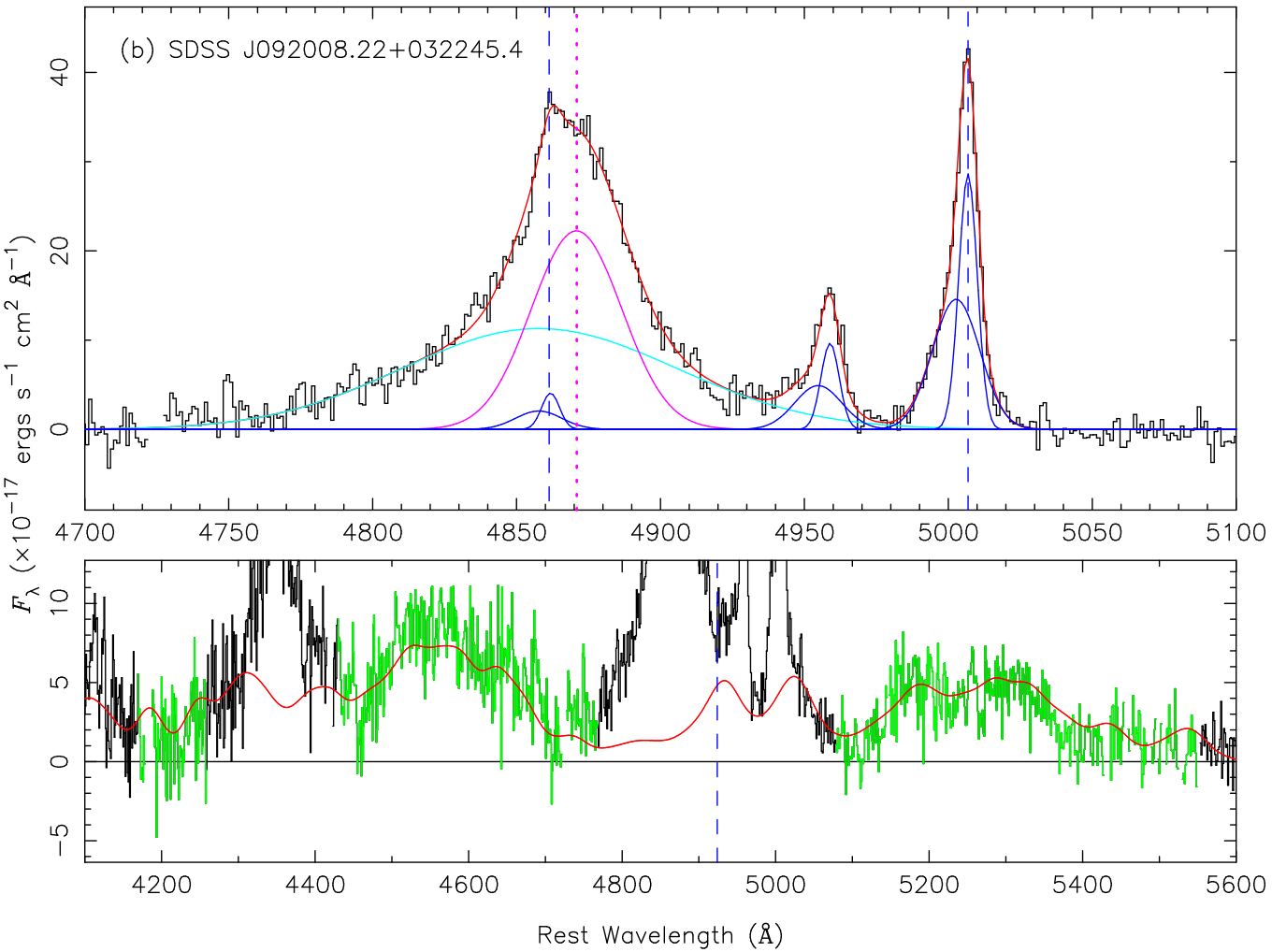
- S/N $>$ 10
- P $<$ 0.0027 (3σ)
- FWHM error $<$ 10%

664 sources

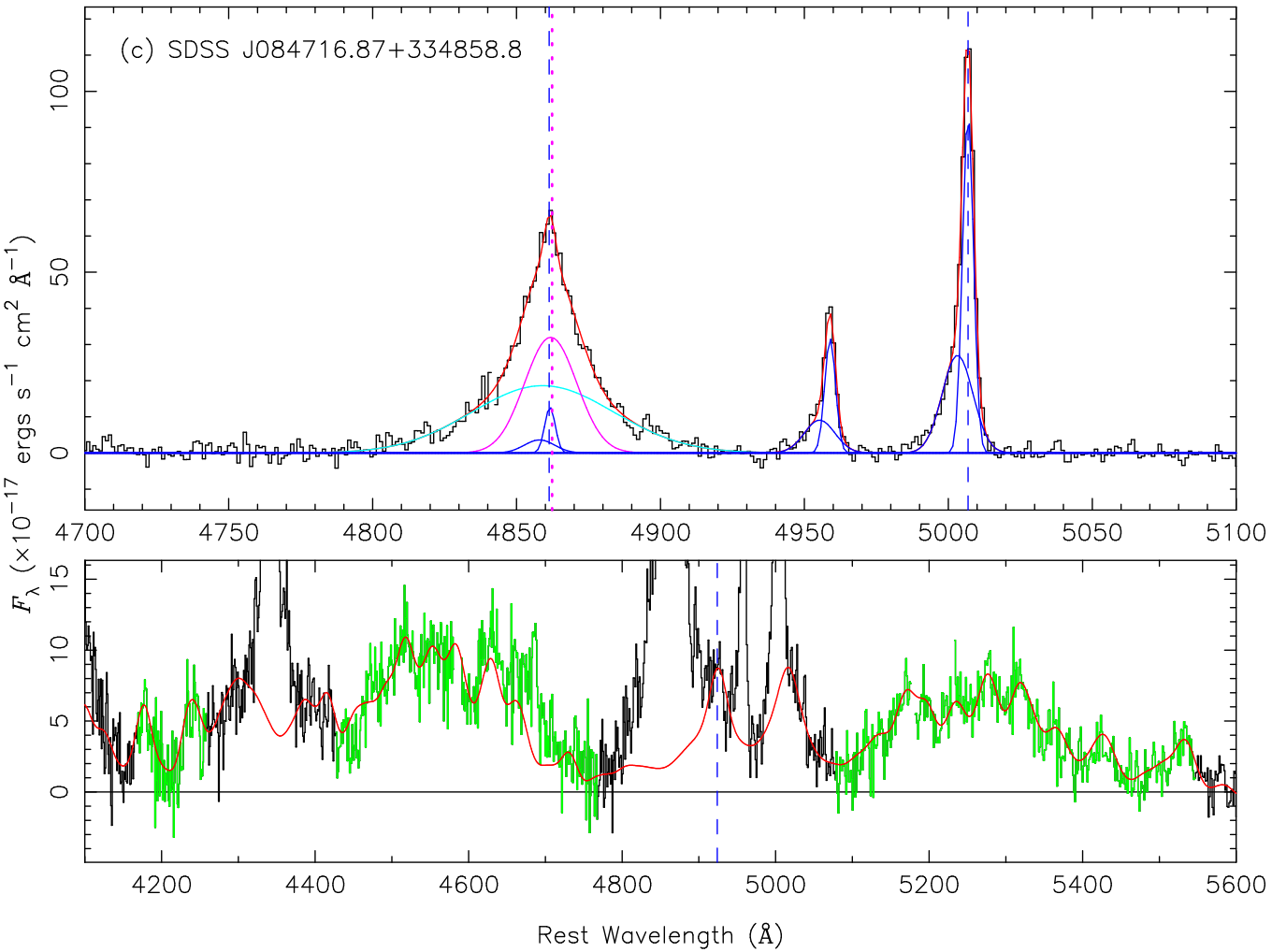
Examples


(a) SDSS J094603.94+013923.6
F_λ ($\times 10^{-17}$ ergs s^{-1} cm^{-2} Å^{-1})
Rest Wavelength (Å)

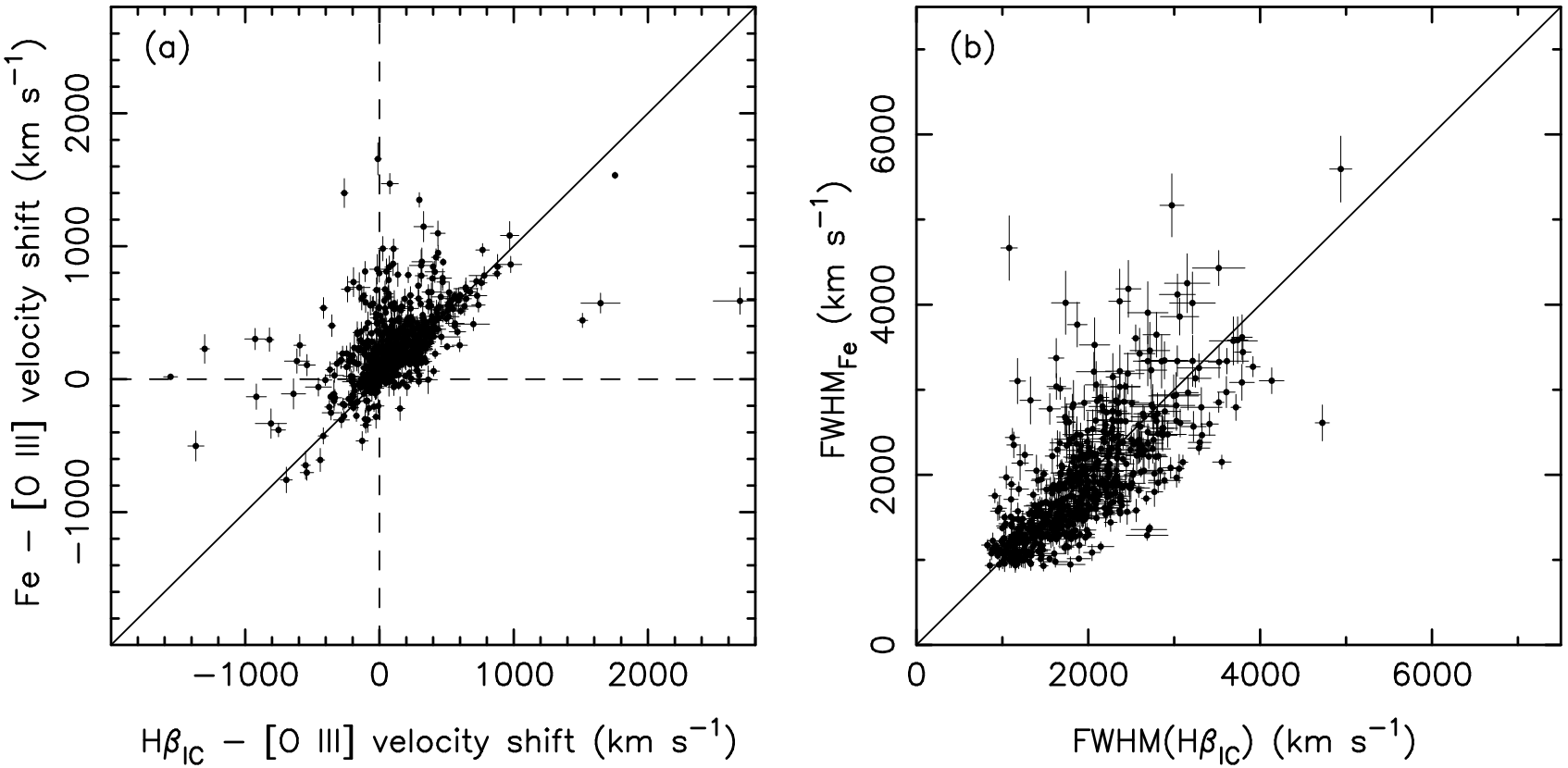
Examples


(b) SDSS J092008.22+032245.4
F_λ ($\times 10^{-17}$ ergs s^{-1} cm^{-2} Å^{-1})
Rest Wavelength (Å)

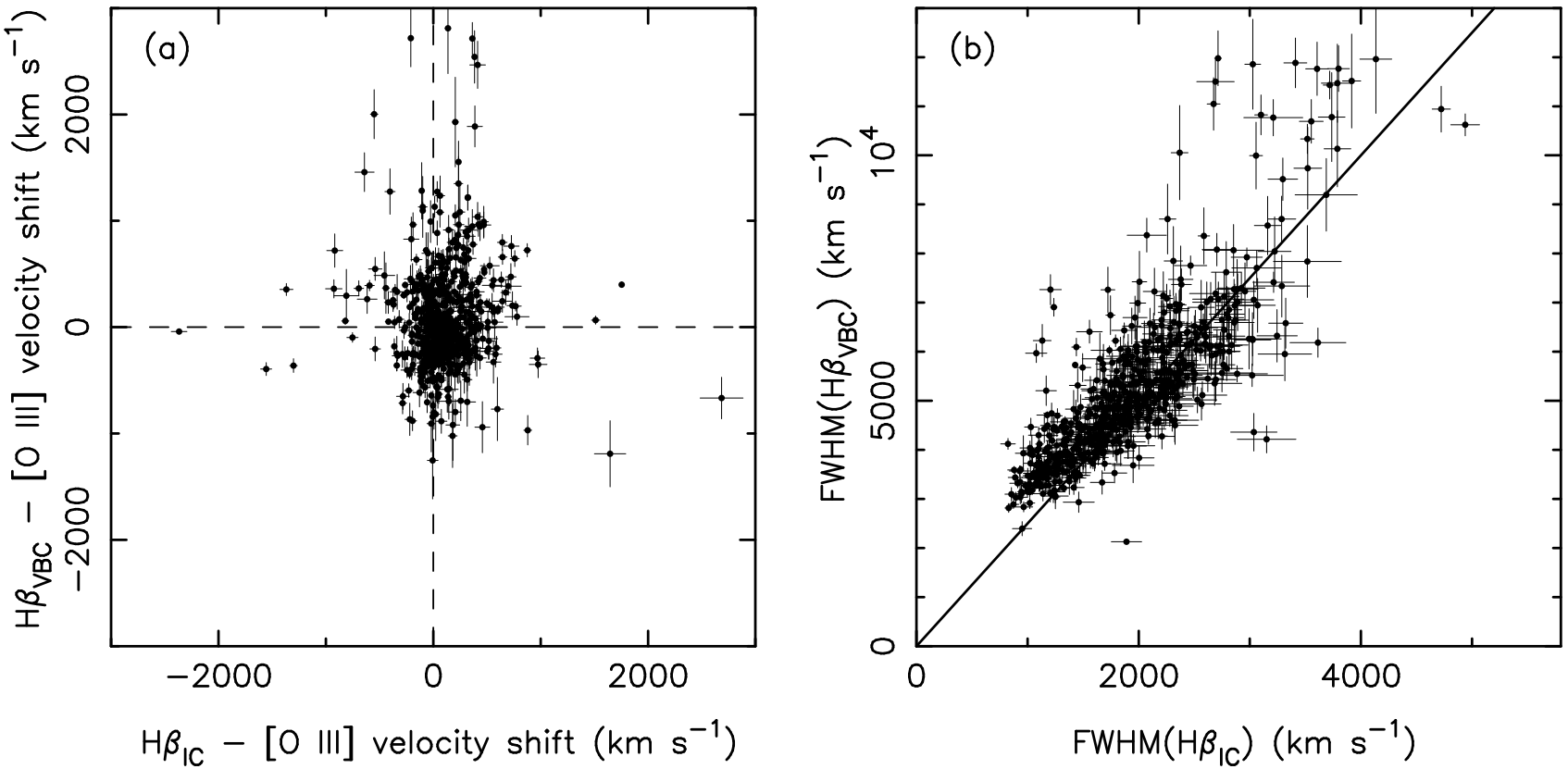
Examples


(c) SDSS J084716.87+334858.8
F_λ ($\times 10^{-17}$ ergs s^{-1} cm^2 Å^{-1})
Rest Wavelength (Å)

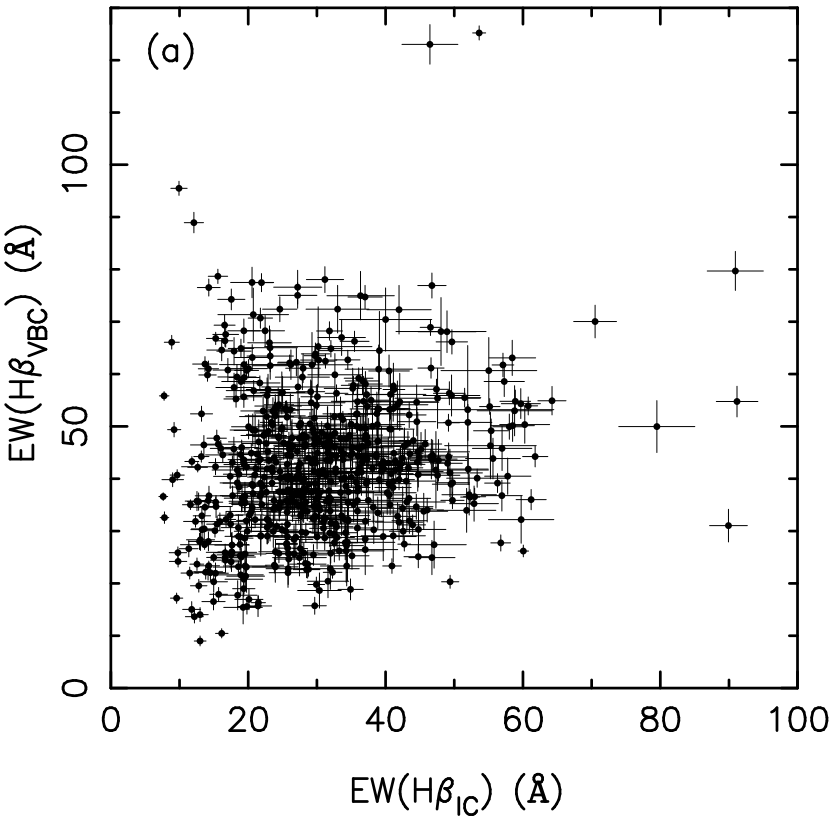
The kinematics of $H\beta_{IC}$ and Fe II are same

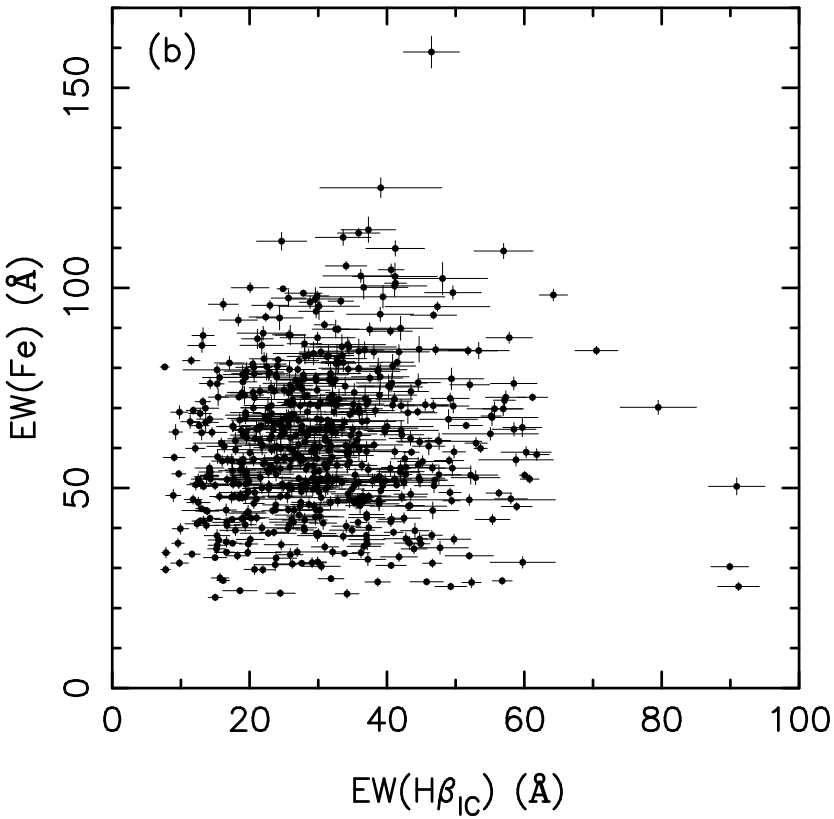


$H\beta_{IC}$ and $H\beta_{VBC}$ are two kinematically different components



ILR and VBLR have different emission





Summary

- The majority of quasars show redshifted Fe II emission lines.
- FWHM(Fe) is systematically narrower than FWHM($\mathrm{H}\beta_{\mathrm{BC}}$).
- The shift of Fe II increases with decreasing Eddington ratio.
- Conventional Hβ broad line region consists of two component: very broad line region (VBLR) and intermediate-line region (ILR) which is associated with the Fe II emission.

- We suggest that Fe II and the $\mathrm{H}\beta_{\mathrm{IC}}$ both trace an inflowing component at the outer portion of the BLR.

Future works

- Fe II shift variability
- Variability of each Hβ components
- Fe II/H$\beta_{\rm IC}$: physical condition of the ILR
- Outflow (C IV) + disk (H$\beta_{\rm VBC}$) + inflow (H$\beta_{\rm IC}$+Fe II)

THANK YOU!