
This is an electronic reprint of the original article.
This reprint may differ from the original in pagination and typographic detail.

Bon, E.; Marziani, P.; Berton, M.; Bon, N.; Antonucci, R.; Gaskell, M.; Ferland, G.

Fe II velocity shifts in optical spectra of type 1 AGN

Published in:
Proceedings of Science

DOI:
[10.22323/1.328.0007](https://doi.org/10.22323/1.328.0007)

Published: 01/01/2018

Document Version
Publisher's PDF, also known as Version of record

Published under the following license:
CC BY-NC-ND

Please cite the original version:
Bon, E., Marziani, P., Berton, M., Bon, N., Antonucci, R., Gaskell, M., & Ferland, G. (2018). Fe II velocity shifts in optical spectra of type 1 AGN. *Proceedings of Science*, 328. <https://doi.org/10.22323/1.328.0007>

This material is protected by copyright and other intellectual property rights, and duplication or sale of all or part of any of the repository collections is not permitted, except that material may be duplicated by you for your research use or educational purposes in electronic or print form. You must obtain permission for any other use. Electronic or print copies may not be offered, whether for sale or otherwise to anyone who is not an authorised user.

Fe II velocity shifts in optical spectra of type 1 AGN

E. Bon^{1*}, P. Marziani², M. Berton^{3,4}, N. Bon¹, R. Antonucci⁵, M. Gaskell⁶, G. Ferland⁷

¹*Belgrade Observatory, Belgrade, 11060, Serbia;*

²*INAF, Osservatorio Astronomico di Padova, Padova, 35122, Italy;*

³*Finnish Centre for Astronomy with ESO (FINCA), University of Turku, 20014, Finland;*

⁴*Aalto University Metsähovi Radio Observatory, Kylmälä, 02540, Finland;*

⁵*Department of Physics, University of California at Santa Barbara, CA 93106-9530, USA;*

⁶*Department of Astronomy & Astrophysics, University of California at Santa Cruz, CA 95064, USA;*

⁷*Department of Physics and Astronomy, University of Kentucky, Lexington, KY 40506, USA.*

E-mail: ebon@aob.rs

Here we present a critical view of practical problems in the analysis of optical Fe II emission lines of Type 1 AGN spectra. Besides the very complex and unclear physical interpretation of the Fe II template shape, there are other issues that might affect the results of Fe II contribution as well (like the S/N, the AGN continuum component modelling, the complex shapes of other broad and narrow emission lines that are blending in the same part of the spectrum, the galactic host stellar component that could lead to mimicking of the Fe II template shape on some parts of spectrum, etc.). In this paper we concentrate particularly on the claims of possibility that in some objects Fe II could be strongly shifted to the red. We examine the effects in the fitting procedure that could artificially lead to such results.

Revisiting narrow-line Seyfert 1 galaxies and their place in the Universe - NLS1 Padova

9-13 April 2018

Padova Botanical Garden, Italy

*Speaker.

1. Introduction

We examine the question whether the substantial redshifts of the optical Fe II lines (often $> 2000 \text{ km s}^{-1}$) that are reported in [1] are real. Sulentic et al. [2] claimed that large Fe II shifts were not real and that Fe II emission could not be well characterized in case Fe II is weak and relatively broad. Subsequent work shall left the issue open. Conversely, Ferland et al. (2009) [3] proposed that these shifts could be due to preferentially an inflowing motion of gas. But the claimed red shifts are huge ($> 2000 \text{ km/s}$). Could they be real? Could it be that the fitting procedures is artificially causing the apparent shifts?

In order to ascertain the reality of the shifts we performed a dedicated analysis of the spectra indicated by Hu et al. as the best examples of high amplitude redshifts. In the following we describe our selection criteria, our method of analysis, our main results and we discuss some interpretations also outlining the main difficulties in the optical Fe II measurements.

There are several serious problems in the analysis of optical Fe II emission lines of type-1 AGN spectra. The most widely employed technique involves an empirical template based on the Fe II spectrum of the NLSy1 galaxy IZw1[4] or on theoretical model template from photo-ionization computations [5].

In this short contribution we will address mainly technical issues of the fitting procedure, leaving to a possible following paper more complete analysis of the interpretation of the Fe II emission (Gaskell et al. in preparation).

This problem is particularly important for our comprehension of the narrow-line Seyfert 1 (NLS1) phenomenon (Osterbrock & Pogge 1985)[6]. Often considered young AGN (Mathur 2000)[7], some authors proposed that they are instead sources with a flattened broad-line region observed at very low inclination (Decarli et al. 2008)[8]. The presence of Fe II red shifts found by Hu et al. (2008), along with the high incidence of blue shifted [O III] in NLS1s (Komossa et al. 2008)[9], produced another hypothesis. Boroson (2011)[10] suggested that NLS1s are low inclination objects with strong outflows, which appear as [O III] blueshift, while the Fe II redshifts are produced by inflowing material moving on the BLR disk. Determining whether or not the Fe II shifts are real is, therefore, of paramount importance to confirm (or disproof) this scenario.

2. Sample selection and Data analysis

In order to examine the highest Fe II redshifts, and avoid unwanted effects of very weak Fe II emission that in lower S/N spectra we selected objects according the results there obtained in [11], selecting a subsample of Fe II shifted candidates. In order to have significant Fe II emission, we used parameter R_{Fe} that represents the ratio of equivalent widths of Fe II and $H\beta$ broad line (we note that the high R_{Fe} does not necessarily imply strong Fe II emission, since it might result from a weak $H\beta$ broad emission line, but with visual inspection of candidates such weak $H\beta$ could be identified and removed from a sample). We therefore selected a subsample with:

1. Fe II shift is larger then 800 km s^{-1} , and $R_{\text{Fe}} > 0.8$ (in order to select only those objects which have a significant Fe II, selected with the aim to avoid spectra with low contribution of Fe II, but to have a significant shift;

2. FeII Shift of Fe II $> 600 \text{ km s}^{-1}$, $R_{\text{Fe}} > 1$ and whose width of FeII lines FWHM $< 2200 \text{ km s}^{-1}$ that was selected in order to avoid the effects of broadening on the shifts.

We modeled the spectra including all components expected to be present, fitted simultaneously. Particular importance has the Fe II template which was assumed to be as provided by Marziani et al (2009) [12]. The host galaxy spectrum was computed with a spectral population synthesis program and was included in the simultaneous fit of all components. The broad $H\beta$ line was modeled with two components to be consistent with the procedure obtained in Hu et al. (2008) [1].

We used ULYSS code Koleva et al (2009) [13],¹ adopted to fit Sy1 spectra as presented in [14]. Stellar populations synthesis was generated using Miles spectral library [15] in order to fit the wavelength range that includes the $[\text{O II}]\lambda 3727 \text{ \AA}$ line. The FeII template adopted from [12]. Spectra were fitted in the wavelength domain 3700-5700 \AA .

We noticed that the results of fitting in many cases were gathering close to the initial values of the FeII shift, indicating degeneracy of some parameters and possible ending of fitting in local minima. Therefore we made low resolution chi square maps using a grid of FeII shift and the FeII widths, since we noticed that the shifts of Fe II were influenced by the lines widths in the fitting procedure, as described in Bon et al. (2016) [14]. We examined these maps and eliminated the objects showing square maps with many local minima that did not allow clear identification of global minimum (we call it here "bad" maps). In the case of the bad chi square maps there is no defined unique solution for the Fe II template shift and width. An example of "good" and "bad" chi square map with the corresponding fit of each spectrum obtained starting from values of Fe II shift and width from the chi square map, is presented in Fig. 1. From total of 260 spectra, there were 69 that we selected as "good".

Besides the complex and unclear physical interpretation of the Fe II template shape, other issues that might affect estimates of the Fe II contribution are:

- 1) S/N ratio,
- 2) AGN continuum shape,
- 3) complex shapes of other blended broad and narrow line,
- 4) shape of stellar continuum which could be mistaken for the Fe II template shape in some regions.

Low signal to noise ratio matters because it could lead to artificial broadening of the Fe II emission lines (we assumed that the broadening of Fe II should be similar to, or smaller value than of broadening of $H\beta$ broad emission line, see for example [16]). AGN continuum is often uncertain due to contamination by strong broad and blended emission lines. For example $H\beta$ and $[\text{O III}]\lambda 4959, 5007 \text{ \AA}$ form a blend that is difficult to deconvolve because of the complexity of the $[\text{O III}]$ line profile, which is rarely reproducible with a single Gaussian component. The stellar continuum of the underlying host galaxy deserves a special attention. It can mimic the Fe II emission in the spectral range short wards of the $H\beta$ line (Bon et al. in preparation).

3. Results

Using the stellar galactic host component as a kinematic reference frame, we calculated shifts

¹The ULYSS full spectrum fitting package is available at: <http://ulyss.univ-lyon1.fr/>

of emission lines.

We find that in general Fe II shifts are correlated with H β broad line shifts. The result of correlation coefficient between these two shifts is 0.55 with null hypothesis value $P=3e-5$. The paired differences of Fe II and H β broad line shifts are modest with the average shift of about 200 km s⁻¹. We were unable to detect shifts as large as those found in Hu et al. (2008)[1]. We found just few cases above 800 km s⁻¹, with the upper limit at 1400 km s⁻¹. Objects with Fe II shifts larger than 800 km s⁻¹ are presented in Table 1.

We found that the analysis of Hu overestimated the parameter R_{Fe} as well as the shift of the Fe II. We selected sources with criteria on R_{Fe} excluding sources with low Fe II emission. However a posteriori analysis show that the average R_{Fe} is smaller than the lower limit that we used in the selection criteria. This could be the effect of neglecting the host stellar contribution in the analysis of Hu et al.[1]. A similar effect is noticed by Sniegowska et al. [17] in the case of measurements obtained by Shen et al. [18]. As for Fe II shifts connection with the orientation hypothesis, suggested in Boroson (2011) [10], our results do not show that the distribution of Fe II against the [O III] line shifts in reference to the stellar host galactic shift (see, Fig. 2) is similar to the one presented in Fig. 1 of Boroson's manuscript[10], neither for the narrow or semi broad [O III] component.

Table 1: Table of objects with Fe II shifts larger than 800 km s⁻¹ in the kinetic reference frame of the stellar host component

Name	R_{Fe}	H β shift (km s ⁻¹)	H β FWHM (km s ⁻¹)	Fe II shift (km s ⁻¹)
SDSSJ013419.11-084714.5	1.48	999	2772	904
SDSSJ141318.96+543202.4	0.74	643	4223	995
SDSSJ133450.43+010219.0	0.82	277	4771	1084
SDSSJ150226.55+544633.5	0.37	328	4011	1105
SDSSJ134503.10+381504.3	0.34	1092	3050	1111
SDSSJ080320.30+294548.8	0.55	562	4844	1308

4. Discussion and Conclusions

Our results confirm the presence of modest shifts among the sources that were identified by Hu et al. (2008) as very shifted sources. The selected subsample with shifts larger than 600 km s⁻¹ that we analyzed here shows that the shifts are not as high as claimed in Hu et al. (2008)[1]. The average shift value is in agreement with the one computed on the complete sample of Hu et al (2008). We find that Fe II shifts are correlated with shifts of H β broad component. The value of the difference between shifts of Fe II and H β shifts are also in agreement with the average value obtained for the complete sample in Hu et al. (2008)[1], indicating a small offset of the Fe II shift of about a 200 km s⁻¹. Such small value of redshift difference has multiple interpretations and the issue will be discussed in a future paper. Similar shifts of Fe II and H β indicate that both emitting regions are connected physically. The small shift amplitude may make it easier to explain

the redshift by a modest radial drift in the outer part of the BLR, as originally suggested by Ferland et al. (2009) [19].

Acknowledgements

This research is part of the projects 176003 "Gravitation and the large scale structure of the Universe" and 176001 "Astrophysical spectroscopy of extragalactic objects" supported by the Ministry of Education and Science of the Republic of Serbia. This research has made use of the NASA/IPAC Extragalactic Database (NED), which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration. Funding for the Sloan Digital Sky Survey has been provided by the Alfred P. Sloan Foundation and the U.S. Department of Energy Office of Science. The SDSS web site is <http://www.sdss.org>. SDSS-III is managed by the Astrophysical Research Consortium for the Participating Institutions of the SDSS-III Collaboration including the University of Arizona, the Brazilian Participation Group, Brookhaven National Laboratory, Carnegie Mellon University, University of Florida, the French Participation Group, the German Participation Group, Harvard University, the Instituto de Astrofísica de Canarias, the Michigan State/Notre Dame/JINA Participation Group, Johns Hopkins University, Lawrence Berkeley National Laboratory, Max Planck Institute for Astrophysics, Max Planck Institute for Extraterrestrial Physics, New Mexico State University, University of Portsmouth, Princeton University, the Spanish Participation Group, University of Tokyo, University of Utah, Vanderbilt University, University of Virginia, University of Washington, and Yale University.

This conference has been organized with the support of the Department of Physics and Astronomy "Galileo Galilei", the University of Padova, the National Institute of Astrophysics INAF, the Padova Planetarium, and the RadioNet consortium. RadioNet has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730562.

References

- [1] C. Hu, J.-M. Wang, L. C. Ho, Y.-M. Chen, H.-T. Zhang, W.-H. Bian et al., *A Systematic Analysis of Fe II Emission in Quasars: Evidence for Inflow to the Central Black Hole*, *Astroph. J.* **687** (2008) 78 [0807.2059].
- [2] J. W. Sulentic, P. Marziani, S. Zamfir and Z. A. Meadows, *No Evidence for a Systematic Fe II Emission Line Redshift in Type 1 Active Galactic Nuclei*, *Astroph. J. Lett.* **752** (2012) L7 [1203.5992].
- [3] G. J. Ferland, C. Hu, J. Wang, J. A. Baldwin, R. L. Porter, P. A. M. van Hoof et al., *Implications of Infalling Fe II-Emitting Clouds in Active Galactic Nuclei: Anisotropic Properties*, *Astroph. J. Lett.* **707** (2009) L82 [0911.1173].
- [4] T. A. Boroson and R. F. Green, *The emission-line properties of low-redshift quasi-stellar objects*, *ApJS* **80** (1992) 109.
- [5] F. Brühweiler and E. Verner, *Modeling Fe II Emission and Revised Fe II (UV) Empirical Templates for the Seyfert 1 Galaxy I Zw 1*, *ApJ* **675** (2008) 83.

- [6] D. E. Osterbrock and R. W. Pogge, *The spectra of narrow-line Seyfert 1 galaxies*, *Astroph. J.* **297** (1985) 166.
- [7] S. Mathur, *Narrow-line Seyfert 1 galaxies and the evolution of galaxies and active galaxies*, *Mon. Not. R. Astron. Soc.* **314** (2000) L17 [arXiv:astro-ph/0003111].
- [8] R. Decarli, M. Dotti, M. Fontana and F. Haardt, *Are the black hole masses in narrow-line Seyfert 1 galaxies actually small?*, *Mon. Not. R. Astron. Soc.* **386** (2008) L15 [0801.4560].
- [9] S. Komossa, D. Xu, H. Zhou, T. Storchi-Bergmann and L. Binette, *On the Nature of Seyfert Galaxies with High [O III] λ 5007 Blueshifts*, *Astroph. J.* **680** (2008) 926 [0803.0240].
- [10] T. A. Boroson, *A New Orientation Indicator for Radio-quiet Quasars*, *Astroph. J. Lett.* **735** (2011) L14+ [1105.5161].
- [11] C. Hu, J.-M. Wang, L. C. Ho, Y.-M. Chen, H.-T. Zhang, W.-H. Bian et al., *A Systematic Analysis of Fe II Emission in Quasars: Evidence for Inflow to the Central Black Hole*, *Astroph. J.* **687** (2008) 78 [0807.2059].
- [12] P. Marziani, J. W. Sulentic, G. M. Stirpe, S. Zamfir and M. Calvani, *VLT/ISAAC spectra of the H β region in intermediate-redshift quasars. III. H β broad-line profile analysis and inferences about BLR structure*, *A&Ap* **495** (2009) 83 [0812.0251].
- [13] M. Koleva, P. Prugniel, A. Bouchard and Y. Wu, *ULySS: a full spectrum fitting package*, *Astron. Astroph.* **501** (2009) 1269 [0903.2979].
- [14] E. Bon, S. Zucker, H. Netzer, P. Marziani, N. Bon, P. Jovanović et al., *Evidence for Periodicity in 43 year-long Monitoring of NGC 5548*, *Astroph. J. Supp.* **225** (2016) 29 [1606.04606].
- [15] P. Sánchez-Blázquez, R. F. Peletier, J. Jiménez-Vicente, N. Cardiel, A. J. Cenarro, J. Falcón-Barroso et al., *Medium-resolution Isaac Newton Telescope library of empirical spectra*, *Mon. Not. R. Astron. Soc.* **371** (2006) 703 [astro-ph/0607009].
- [16] V. Cracco, S. Ciroi, M. Berton, F. Di Mille, L. Foschini, G. La Mura et al., *A spectroscopic analysis of a sample of narrow-line Seyfert 1 galaxies selected from the Sloan Digital Sky Survey*, *Mon. Not. R. Astron. Soc.* **462** (2016) 1256 [1607.03438].
- [17] M. Śniegowska, B. Czerny, B. You, S. Panda, J. M. Wang, K. Hryniewicz et al., *Properties of active galaxies at the extreme of Eigenvector 1*, *Astron. Astroph.* **613** (2018) A38 [1701.03694].
- [18] Y. Shen, G. T. Richards, M. A. Strauss, P. B. Hall, D. P. Schneider, S. Snedden et al., *A Catalog of Quasar Properties from Sloan Digital Sky Survey Data Release 7*, *Astroph. J. Supp.* **194** (2011) 45 [1006.5178].
- [19] G. J. Ferland, C. Hu, J.-M. Wang, J. A. Baldwin, R. L. Porter, P. A. M. van Hoof et al., *Implications of Infalling Fe II-Emitting Clouds in Active Galactic Nuclei: Anisotropic Properties*, *Astroph. J. Lett.* **707** (2009) L82 [0911.1173].

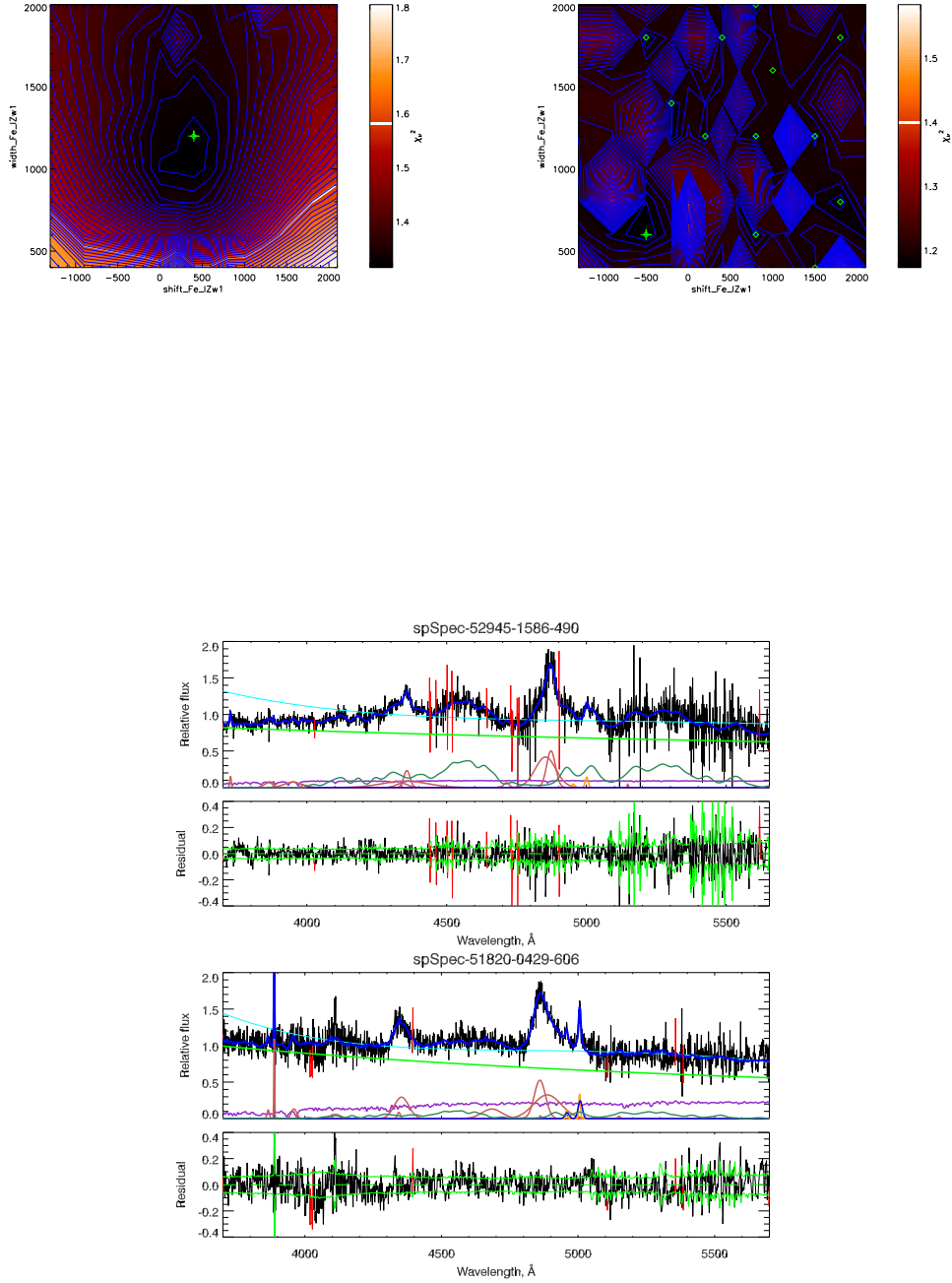


Figure 1: Examples of "good" global minimum (SDSSJ162901.43+304401.3, spSpec-52945-1586-490, top left) and "bad" one (SDSSJ014655.78+135915.4, spSpec-51820-0429-606 top right) on chi square maps of Fe II shift and width parameters (top panel) with corresponding plots of the fitted model for each chi square map (mid and bottom panel). Darker colors correspond to lower value of chi square, with gradient marked with blue iso lines.

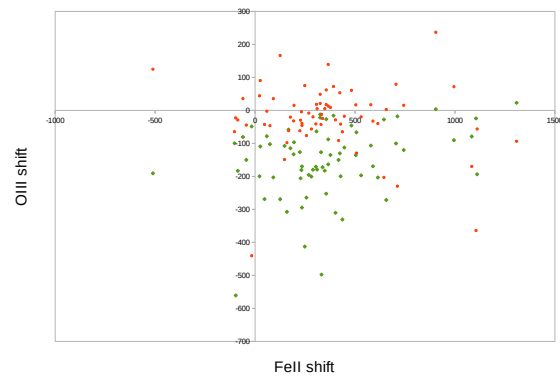


Figure 2: The shift of Fe II template against the [O III] line component shift of narrow (orange) and semi broad Gaussian component (green).