Low ionization lines in Quasars

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Abstract

In order to investigate where and how low ionization lines are emitted in quasars, we are studying a new collection of spectra of the CaII triplet at λ8498, λ8452, λ8662 observed with the VLT Telescope using the ISAAC IR spectrometer. Our sample involves luminous quasars at intermediate redshift, for which CaII observations are almost non-existent. We fit the CaII triplet and the OI λ 8446 line using the Hβ profile as a model. We derive constraints on the line emitting region from the relative strength of the CaII triplet, OI λ 8446 and Hβ.

Introduction

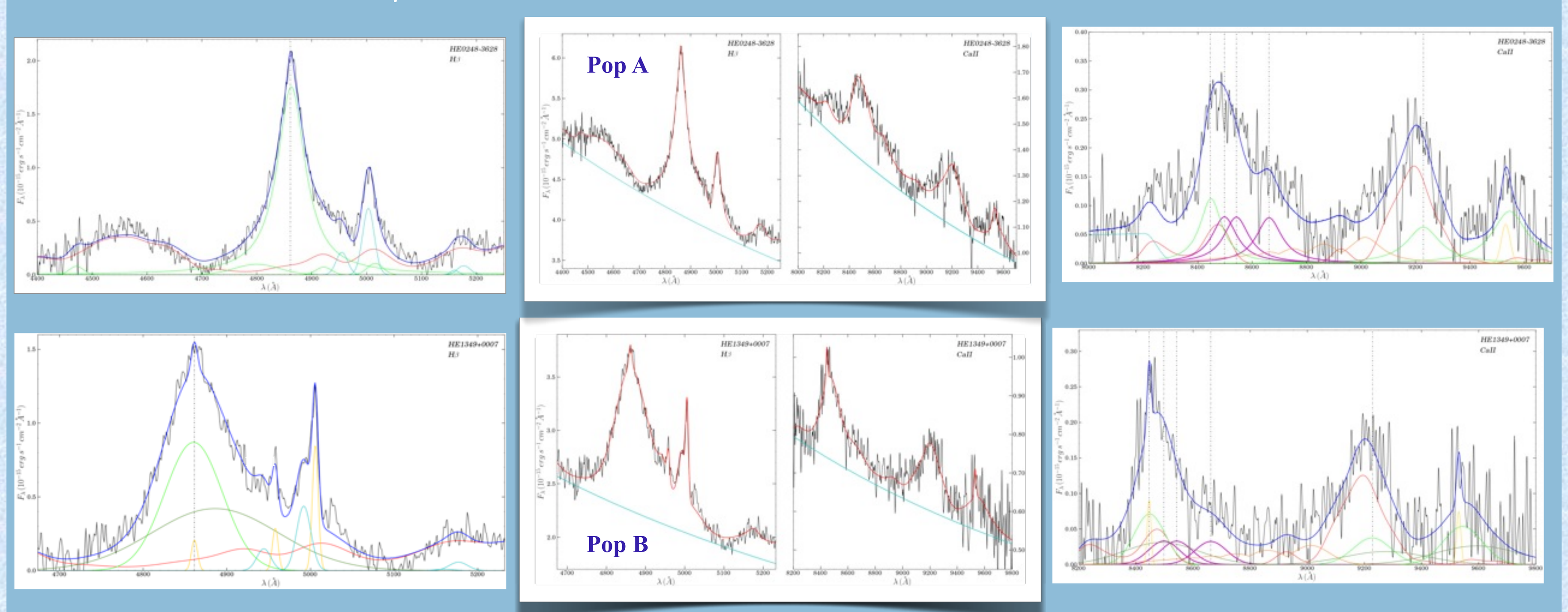
Explaining the origin of Fe emission in quasars is a long-standing problem in AGN research. The extreme complexity of the Fe+ ion makes theoretical model calculations very difficult and line blending makes estimation of FeII width and strength parameters uncertain. The Ca+ ion is, by contrast, far simpler. The ionization potential of neutral Calcium is 6.1 eV so we expect Ca+ ions to exist wherever hydrogen is not fully ionized. Several lines of evidence suggest that CaII IR is produced in the same region where FeII (Dultzin-Hacyan et al., 1999). Ferland and Persson (1989), Joly (1989) and Matsuoka (2007) state that the column density of the region where FeII, CaII and OI 8446 are produced should be very high ($N_c \sim 10^{25}$ cm^{-2}). Dultzin-Hacyan et al. (1999) suggest that this region could be associated with the outer part of an accretion disk. Matsuoka et al. (2007) derive also low ionization and high density. The present works extends the study of CaII to high luminosity and intermediate redshift. We take advantage of an interpretation of the Hβ profile of broader sources (Population B) that considers a very broad and a very broad component (BC and VBC).

The sample and observations

Our sample includes 14 bright and luminous quasars with 0.847<z<1.638 observed in 2010, 10 B population sources and 4 A population. CaII spectra were obtained with VLT ISAAC. Two typical examples are show in the panel aside.

Object name	z	M_B	Log(R_K)	Sp. T.
HE0005-2355	1.412	-27.6	2.56	B1
HE0035-2853	1.638	-28.1	<0.21	B
HE0043-2300	1.540	-27.9	2.03	A1
HE0048-2804	0.847	-26.0	...	B1
HE0058-3231	1.582	-27.9	<0.24	B1
HE0203-4627	1.438	-27.5	2.07	B2
HE0248-3628	1.536	-28.2	0.55	A1
HE1349+0007	1.444	-28.0	-0.18	B1
HE1409+0101	1.650	-28.3	0.40	B
HE2147-3212	1.543	-28.2	<0.14	B
HE2202-2557	1.535	-28.1	1.80	B1
HE2340-4443	0.922	-26.3	...	A1
HE2349-3800	1.604	-27.4	1.93	B2
HE2352-4010	1.580	-28.8	...	A1

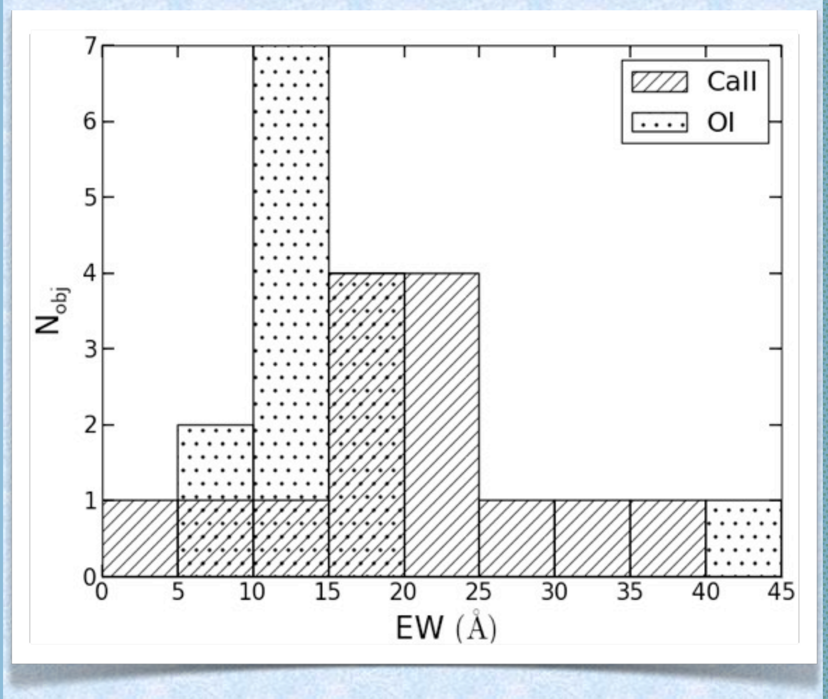
Hβ, OI and CaII spectrum



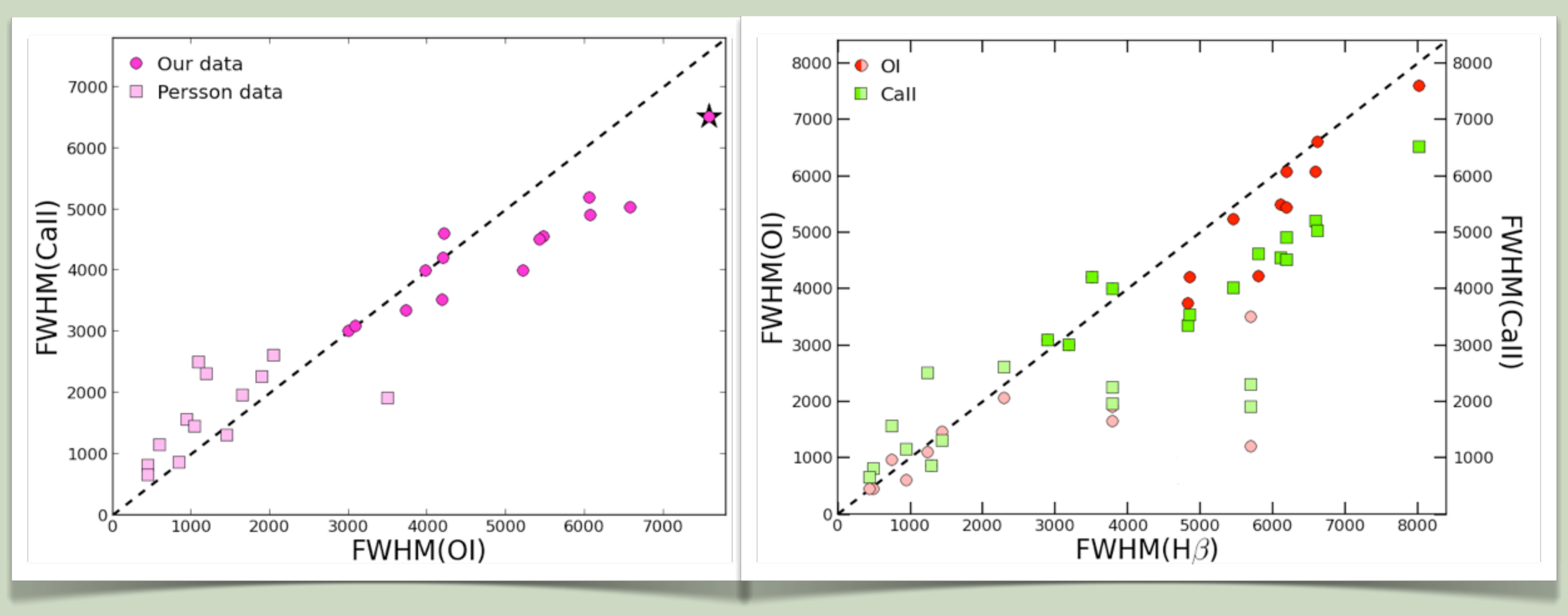
Taking Hβ as a reference, we fit for broad components a Gaussian profile for sources with FWHM($H\beta_{BC}$)≥ 4000 km s^{-1} (B sources) and a Lorenztian for FWHM($H\beta_{BC}$) < 4000 km s^{-1} (A sources). We fit the same components (VBC and BC) for Hβ and OI constrained to similar FWHM and shift. CaII is an optically thick line, therefore we took the same intensity for the three lines. Even if FeII in this region is not strong, we still use a FeII template (García-Rissmann et. al 2012) whose effect is mainly seen at ~9200 Å. High order Paschen lines are present in all the region forming a pseudo-continuum that is not be negligible down to 8204 Å where the Paschen continuum starts. We can detect this continuum in some cases; however it is usually less than predicted by photoionization calculations. Following Hβ we fit a BC and VBC for Paschen lines in B sources. We found that the underlying stellar absorption of the host galaxy is significant only in one case, with a luminosity contribution of ~50%. The rest of the sample was affected by <10% of the luminosity. In that one case (starred point) we subtracted a stellar population synthesis model with bulge mass of 1.13 x10^{12} and age of 7.5 Gyr, with a metallicity of 2Z_{sol}.

Is CaII detected? The distribution of EW

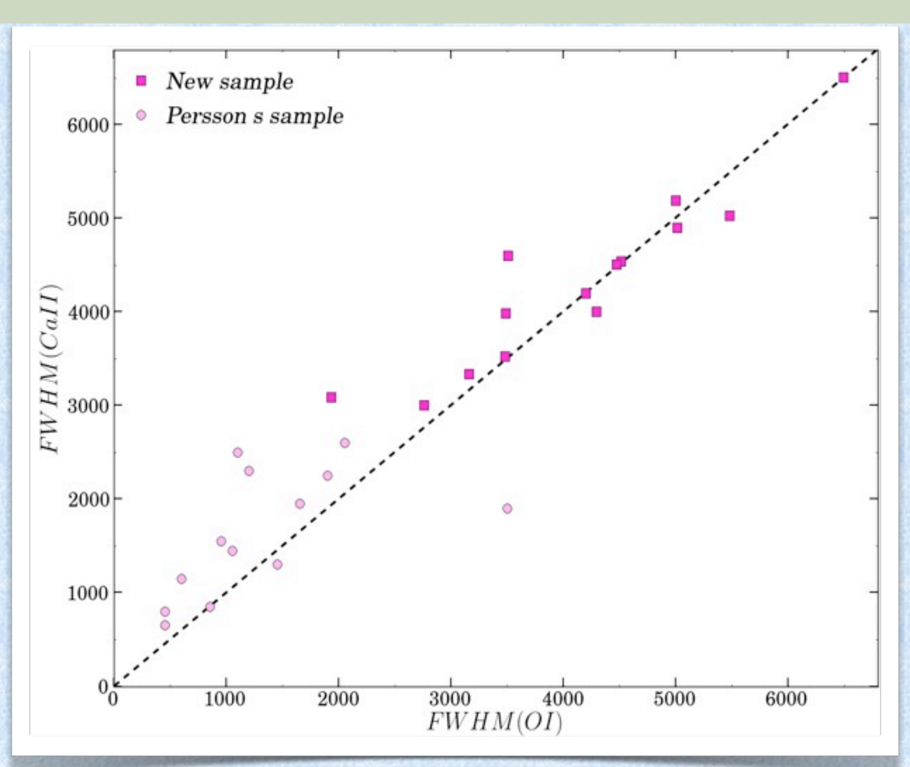
Unlike others samples (Persson 1988, Matsuoka et al. 2007), our sample was not selected considering FeII intensity. Even so, we could detect the emission of CaII in all sources. Taking bins of 5 Å, we can see that EW(CaII) is distributed over a wide range, whereas EW(OI) is not. This result indicates that OI 8446 is unlikely to be emitted in the very same region of the CaII triplet.



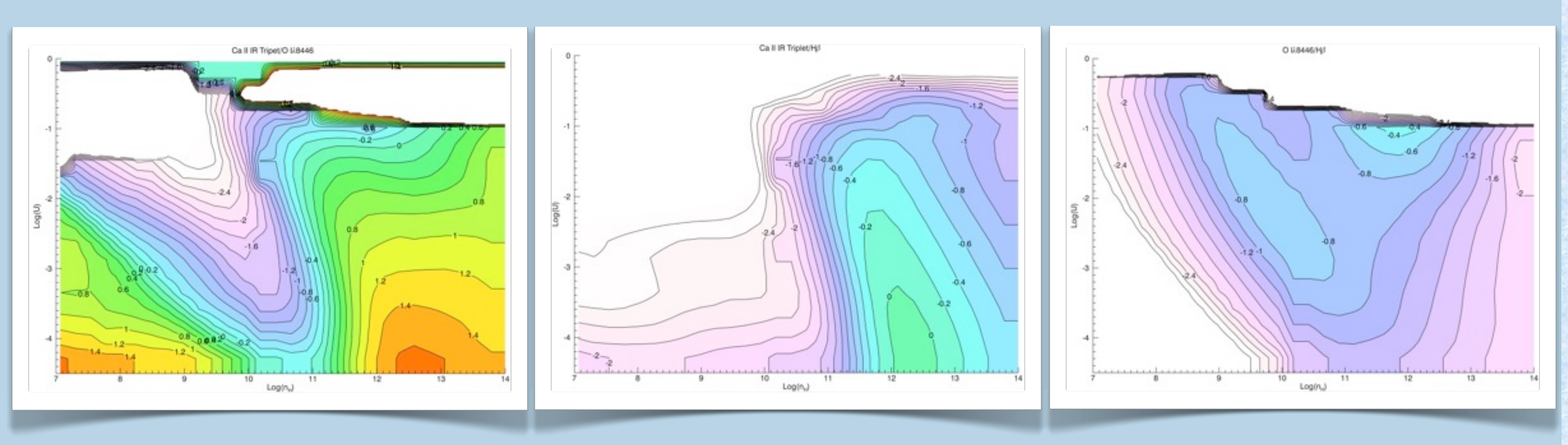
Where is CaII emitted?



The figures above show that when we combine our data and Persson's (1988) sample, the original correlation between FWHM of CaII, OI 8446, and Hβ is basically confirmed with one notable difference. The systematically lower FWHM of CaII is due to OI 8446 profile model including a BC and a VBC. Ca II line width tends to be lower than for OI 8446. In turn, Hβ BC+VBC tends to be consistent with OI but broader than CaII. These trends indicate that a good fit to the profile blend is possible if emission of Hβ and OI are assumed to occur in both a Broad Line Region and a Very Broad Line Region associated to the BC and VBC respectively. CaII appears to be mainly emitted in the BLR associated with the BC. The plot below shows that CaII and OI BC FWHM are very similar, although OI may be somewhat narrower than CaII.



Observations vs. Photoionization models



Even if Hβ, OI and CaII may follow the same dynamics within the low-ionization BLR, the physical conditions favoring their emission are not the same. The figures above show photoionization models with $N_c=10^{23}$cm^{-3}. The average flux ratios for our sample are:

log(CaII/OI)≈-0.01

log(OI/Hβ)≈-0.8

log(CaII/Pa9)≈0.35.

The CLOUDY (Ferland et al. 2013) photoionization predictions are shown as a function of ionization parameter and density. They consistently indicate $n_H>10^{11}$ cm^{-3} and $n_H\sim10^{11.5}$ cm^{-3} for CaII in agreement to previous works. The ionization parameter is constrained to be log U < -1.5. The OI line is consistent with somewhat lower density and higher ionizing photon flux.

Conclusions

CaII has been associated to strong FeII emission in Seyfert and Quasars (i.e., with Pop. A sources). We could observe it in quasars that do not necessarily satisfy this condition. Our sample extends previous samples including several quasars with broader lines (Pop. B). OI and CaII are blended; however there is always significant CaII emission, even when OI 8446 dominates the blend with BC+VBC emission. For the first time we included high order Paschen lines and Paschen continuum. Photoionization models confirm that we need high density in the BLR to account for significant CaII emission.

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