QUASARS IN CRISIS
THE ROYAL OBSERVATORY, EDINBURGH
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Main Trends of the Main Sequence
Un-Fudging The Virial factor

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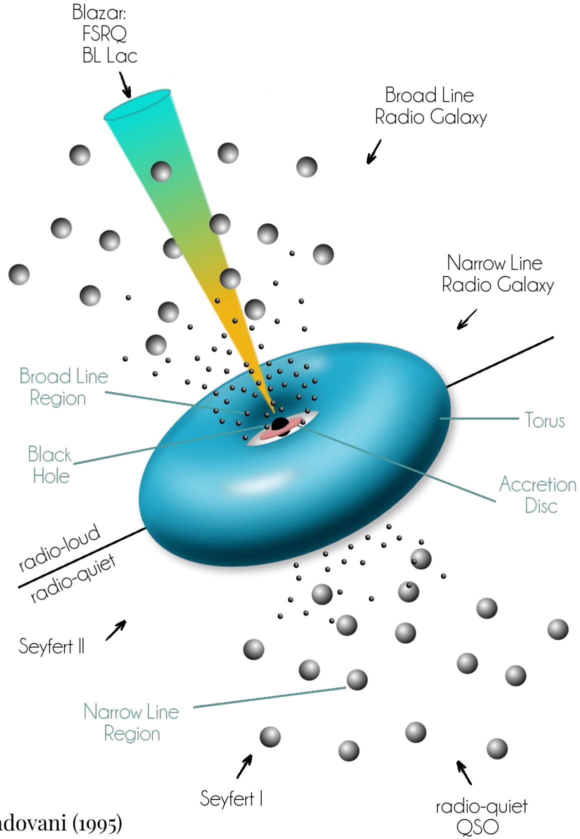
cft

CAMK PAN

The “fudgy” Virial factor (f)



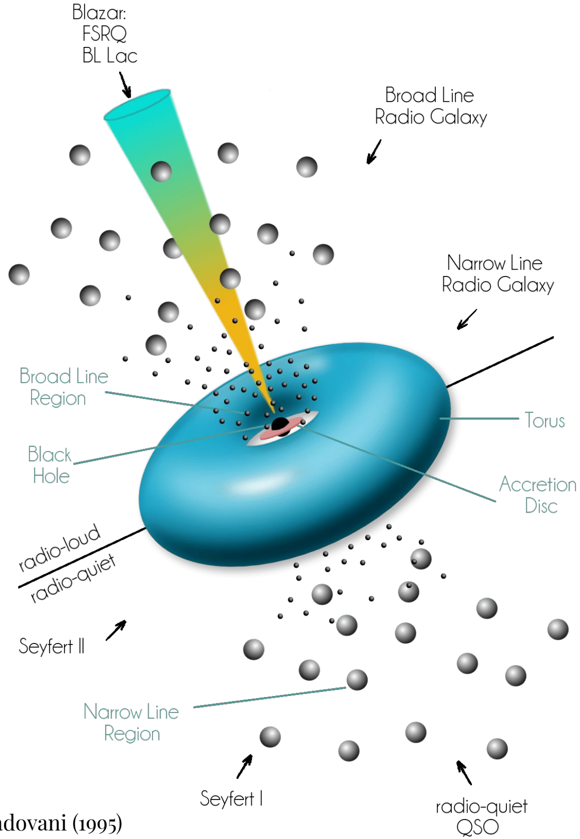
F. Krauß after Urry & Padovani (1995)

“How does one evaluate and interpret the scaling factor f ?”

Collin et al. (2006)

Prof. Suzy Collin-Zahn
Chercheur retraitée associée à
l’Observatoire de Paris

The "fudgy" Virial factor (f)

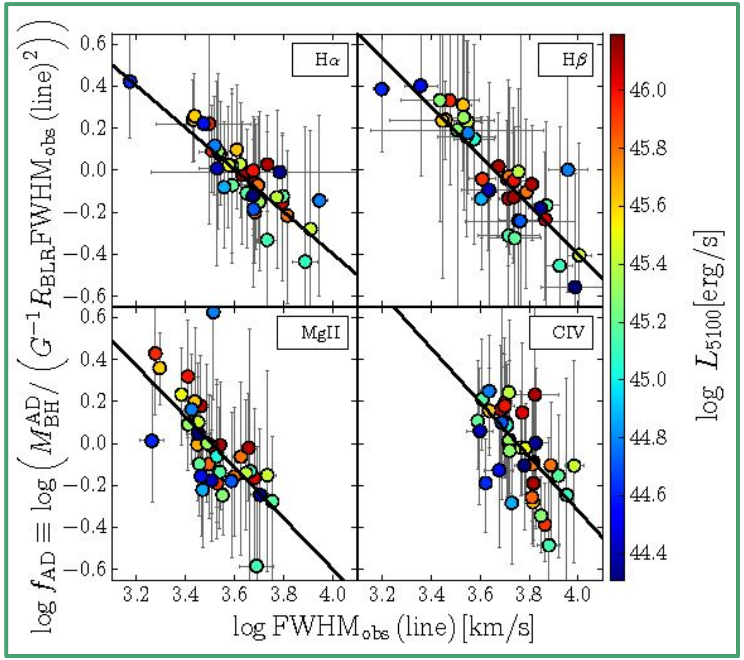


F. Krauß after Urry & Padovani (1995)

"We are characterizing the size and velocity dispersion of the BLR by single numbers, we are subsuming a lot of our ignorance of AGN structure into this single parameter (Collin et al. 2006)"

"Given the complicated structures of BLRs inferred from the velocity-binned RMs, f is most likely to vary from object to object (e.g. Xiao et al. 2018)"

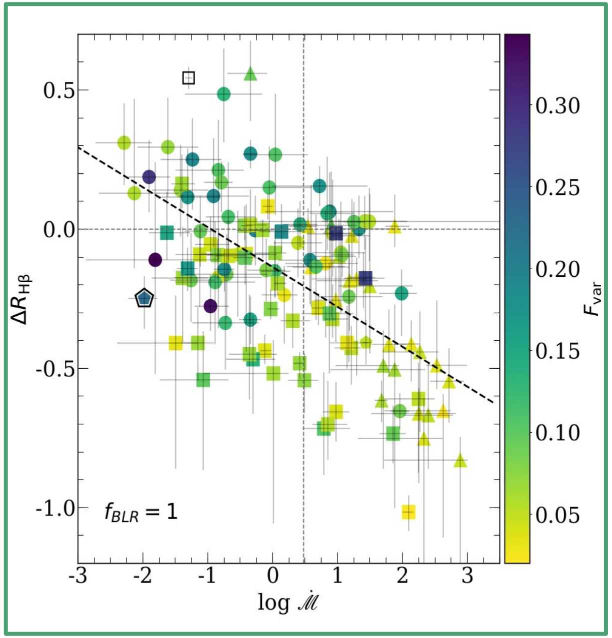
"By modelling simultaneously the AGNs continuum light curve and Hβ line profiles, some BLRs dynamical models found that there was a wide range of f and it has a correlation with the inclination angle, or M_{BH} (e.g. Pancoast et al. 2014; Grier et al. 2017a; Williams et al. 2018; Pancoast et al. 2018; Li et al. 2018)"

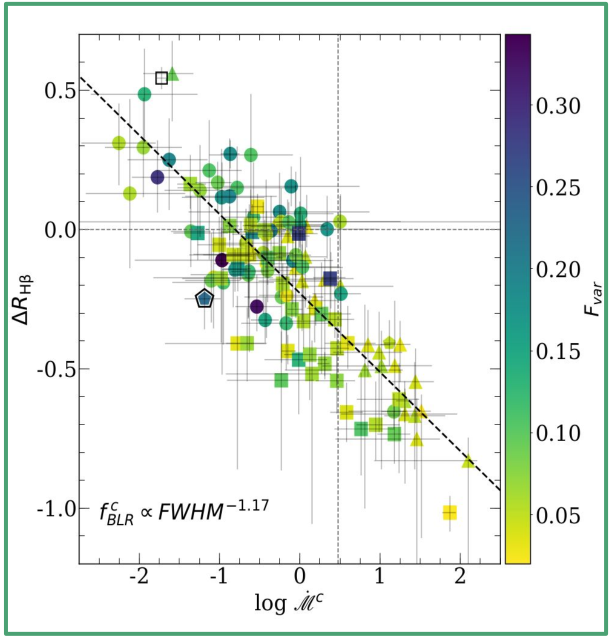


“variable” Virial factor

Mejía-Restrepo et al. (2017)

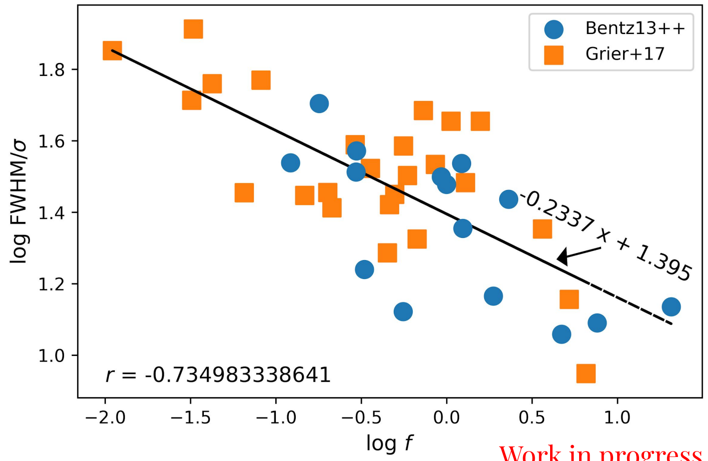
“variable” Virial factor





Martínez-Aldama et al. (2019)

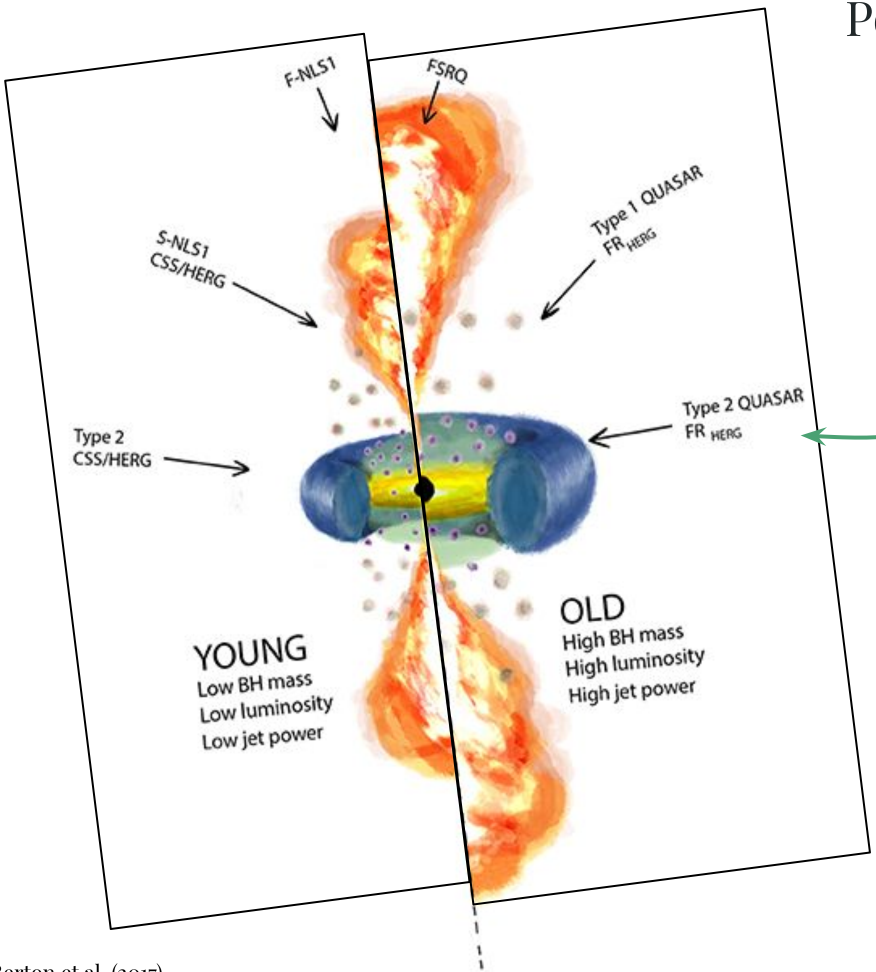
“variable” Virial factor

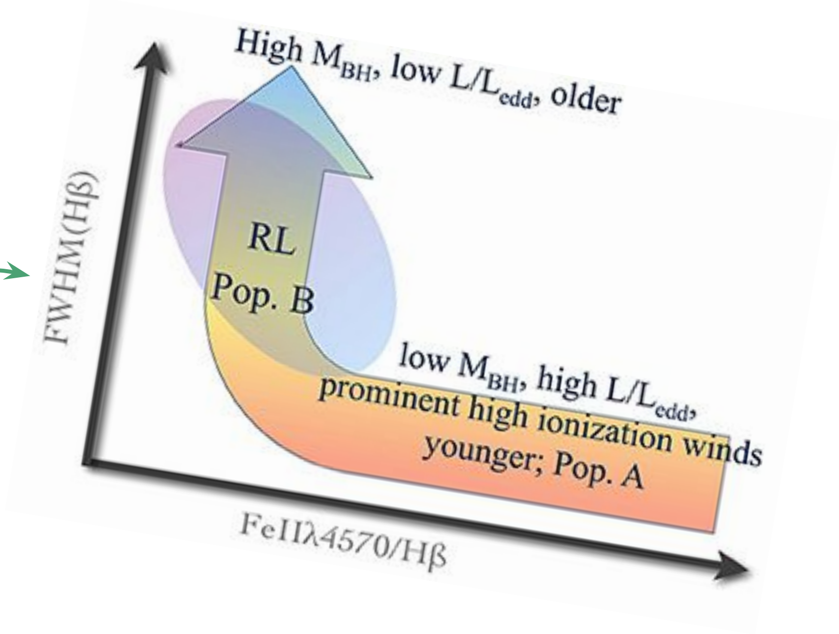


Work in progress

Panda & Martínez-Aldama (in prep.)

Possible Evolutionary scheme along the EV1





Berton et al. (2017)

Fraix-Burnet et al. (2017)

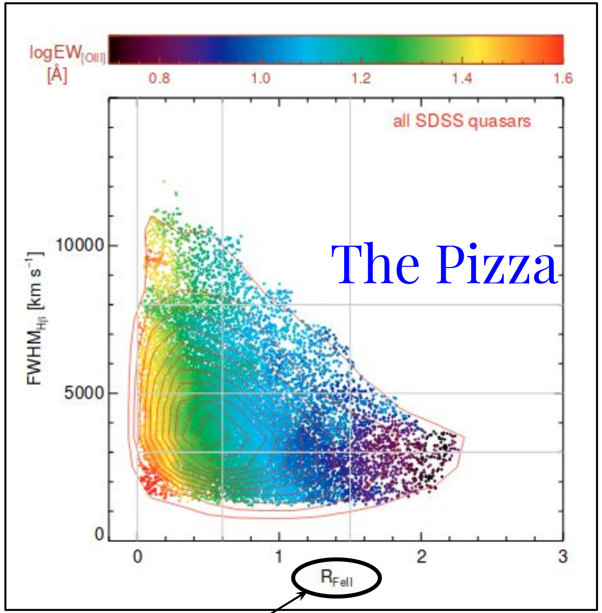
QUASAR MAIN SEQUENCE

• Schema for the Eigenvector 1

Principal Component Analysis (PCA)

- 13 tabulated properties
- Eigenvector 1: FeII - [OIII] anti-correlation
- Peak λ5007 and Hβ FWHM correlation

Boroson & Green (1992)



FeII emission within 4434-4684Å wrt broad Hβ

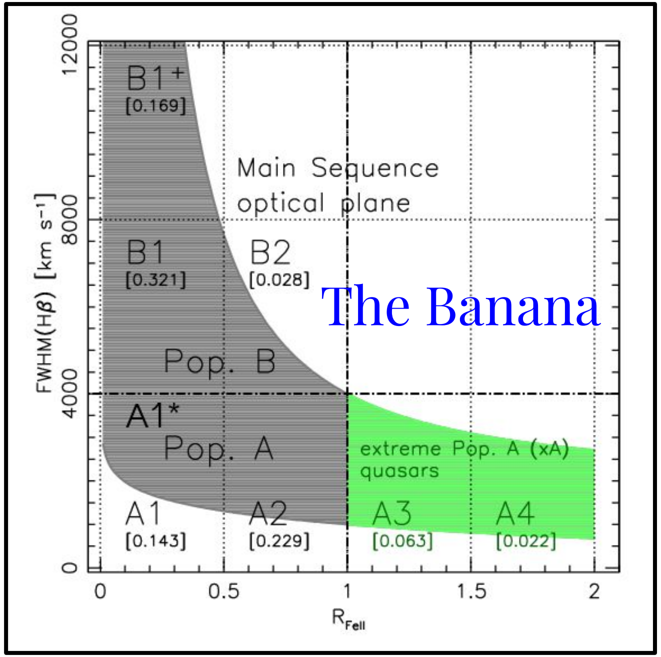
Shen & Ho (2014)

• Schema for the Eigenvector 1

Why this scheme?

- The *Shen & Ho (2014)* use automatic disk fitting to estimate the underlying continuum ⇒ R_{FeII} values likely 'unreliable'
- Also, NOT z-limited!

Śniegowska et al. 2018, *A&A*, 613, 38



Panda et al. (2019b)

“*Looking at it*” differently

Modelling the optical plane

- Mainly as a function of black hole mass & accretion rate
- Theoretical SED shapes, local density, cloud composition

Panda et al. (2017, 2018, 2019a)

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Effect of viewing angle (*f*-factor)

$\kappa = v_{iso} / v_{\kappa}$

$$\boxed{M_{\mathrm{BH}} = f \frac{r_{\mathrm{BLR}} \mathrm{FWHM}^2}{G} = \frac{r_{\mathrm{BLR}} \mathrm{FWHM}^2}{G(4 \cdot (\kappa^2 + \sin^2 \theta))}}$$

Panda et al. (2017, 2018, 2019a)

Panda et al. (2019b)

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➕

account for R_{FeII} values in each spectral type along the MS, in a way consistent with the observational trends in metallicity, density, and SED

Panda et al. (2017, 2018, 2019a)

Panda et al. (2019b)

"*Looking at it*" differently

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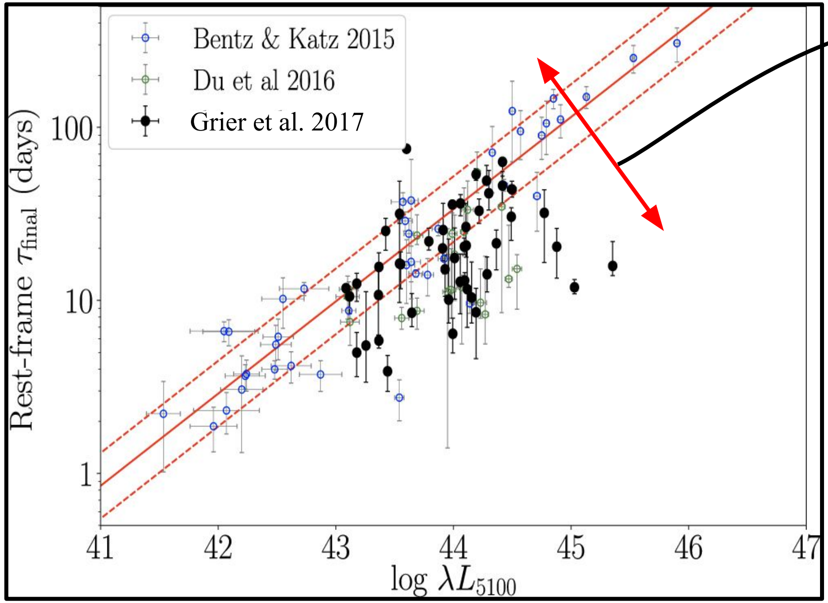
$R_{\rm FeII}$ dependence on $L_{\rm bol}/L_{\rm Edd}$

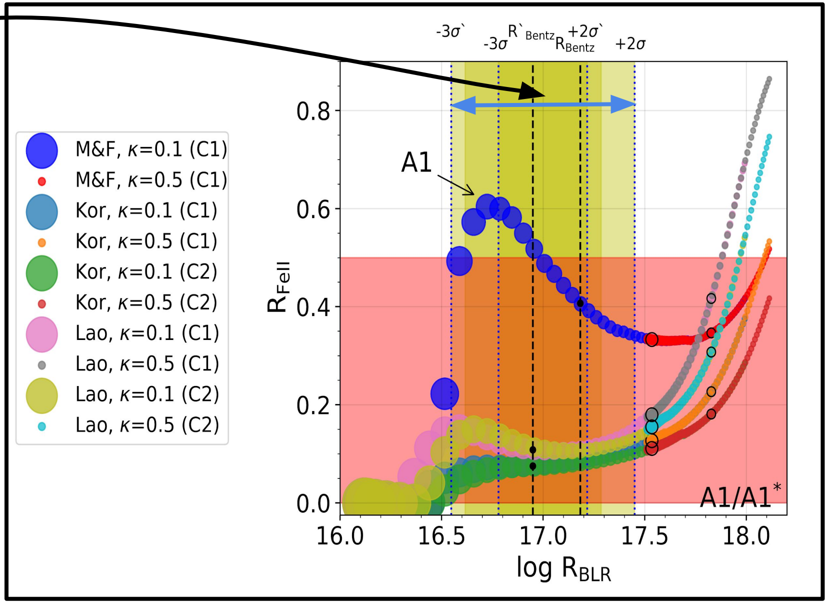
Panda et al. (2017, 2018, 2019a)

Panda et al. (2019b)

Effect of viewing angle (*f*-factor), physical trends

arXiv:1905.01729





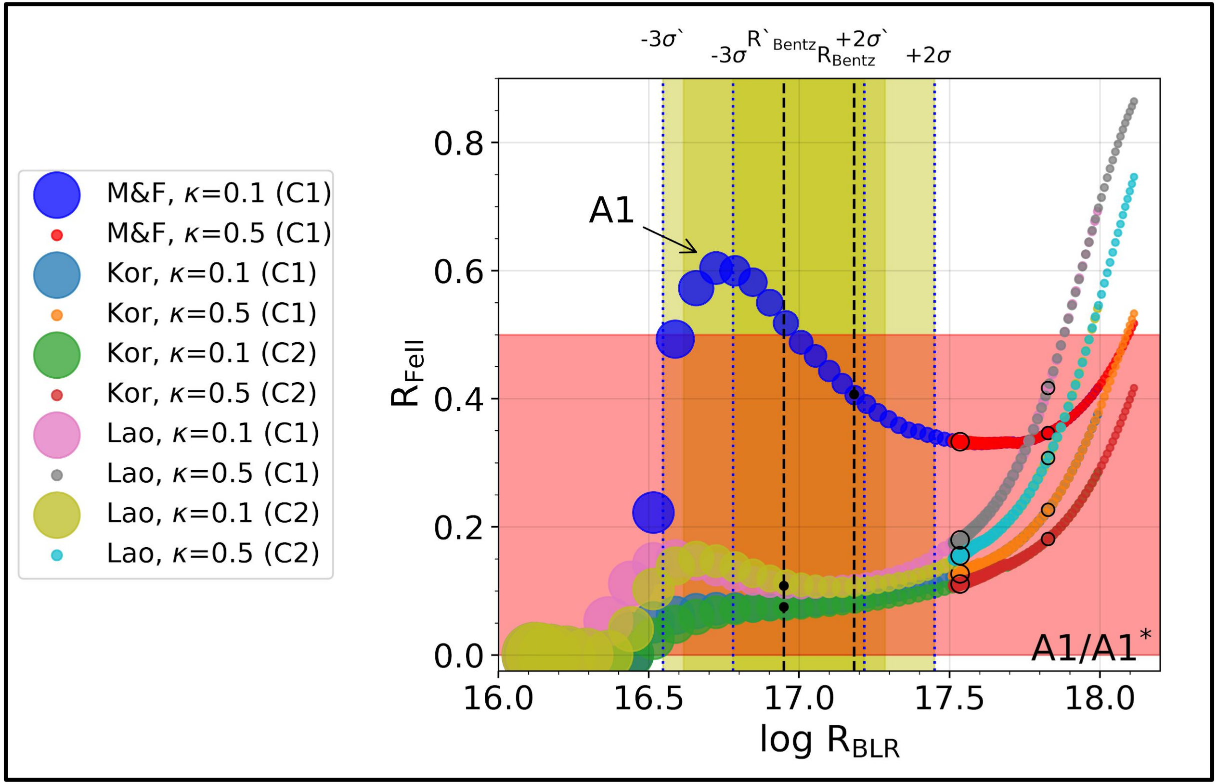
Hβ radius-luminosity (monochromatic at 5100Å) with previous measurements in blue (Bentz & Katz 2015) and green (Du et al. 2016) and in black (Grier et al. 2017). The red solid and dashed lines show the best-fit relation and it's measure scatter from Bentz et al. (2013).

Results from a set of CLOUDY simulations performed on a constant density single BLR cloud assuming M_{BH} = 10^8 $M_{\odot}$ showing the distribution of changing FeII strength with changing BLR sizes computed from the virial relation. Open circles mark the R_{FeII} values expected for θ = 30° and θ = 45°. The color patches (in red) denote the range of R_{FeII} values as expected from observational evidences.

Grier et al. (2017)

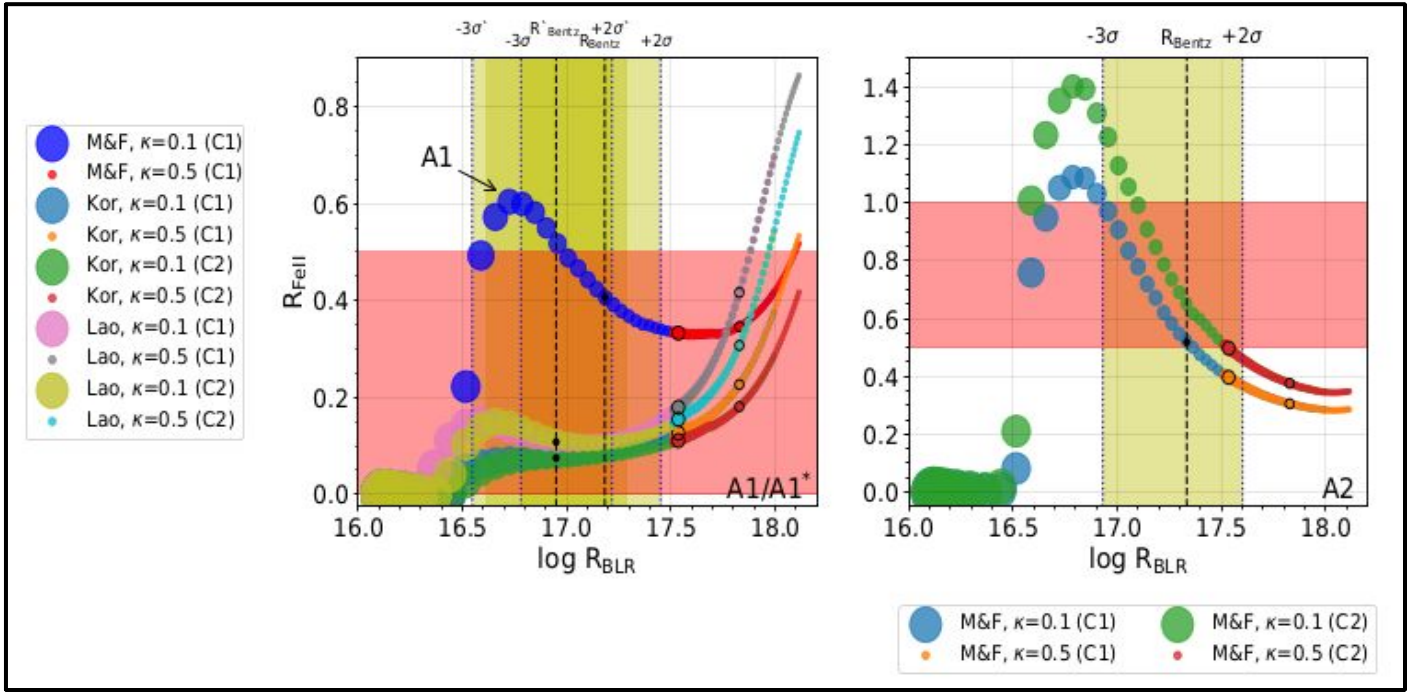
Panda et al. (2019b)

Effect of viewing angle (*f*-factor), physical trends



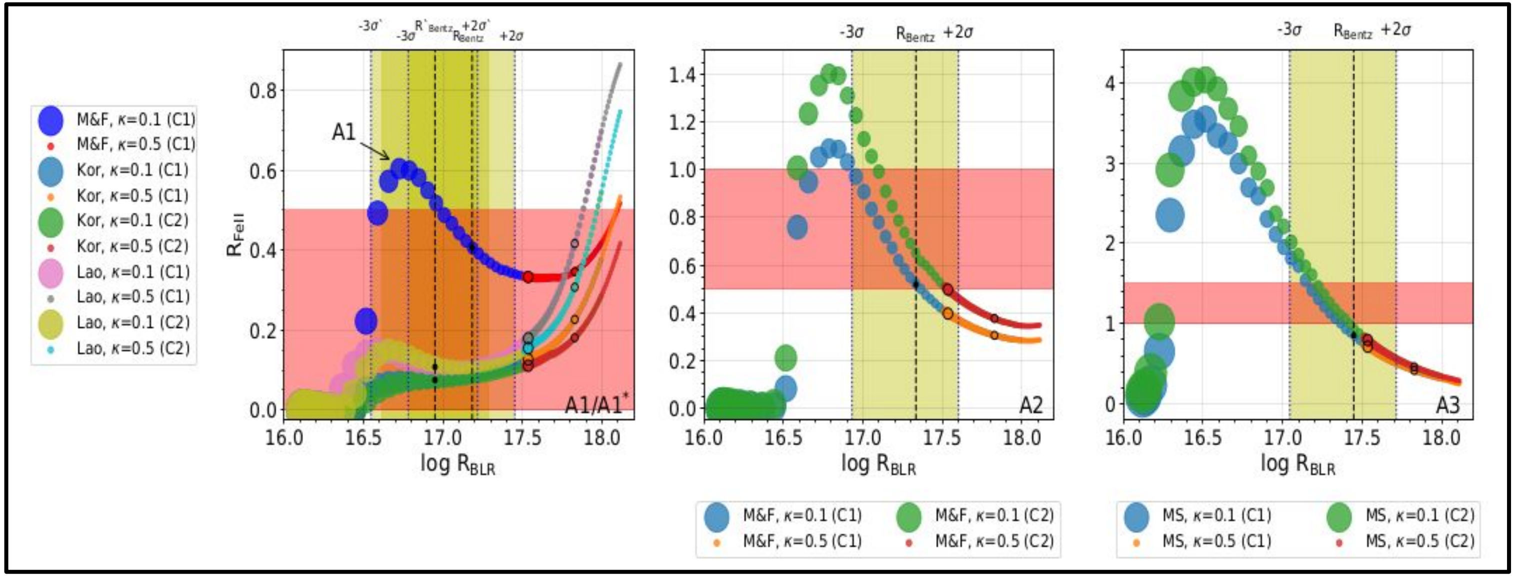
Panda et al. (2019b)

Effect of viewing angle (f-factor), physical trends



Panda et al. (2019b)

Effect of viewing angle (*f*-factor), physical trends



Panda et al. (2019b)

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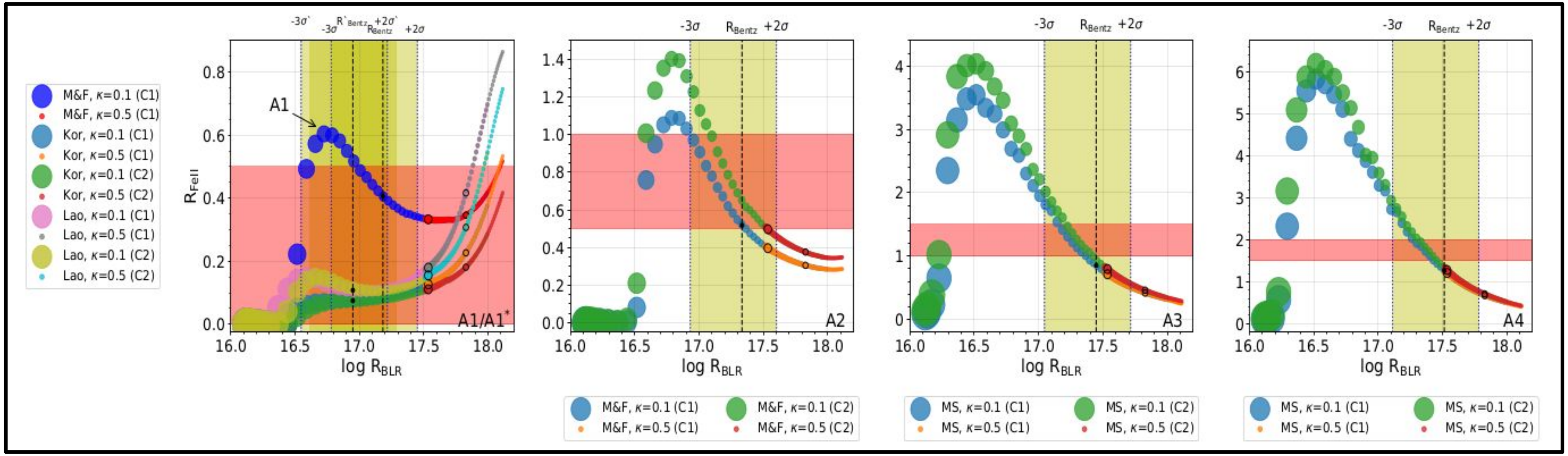
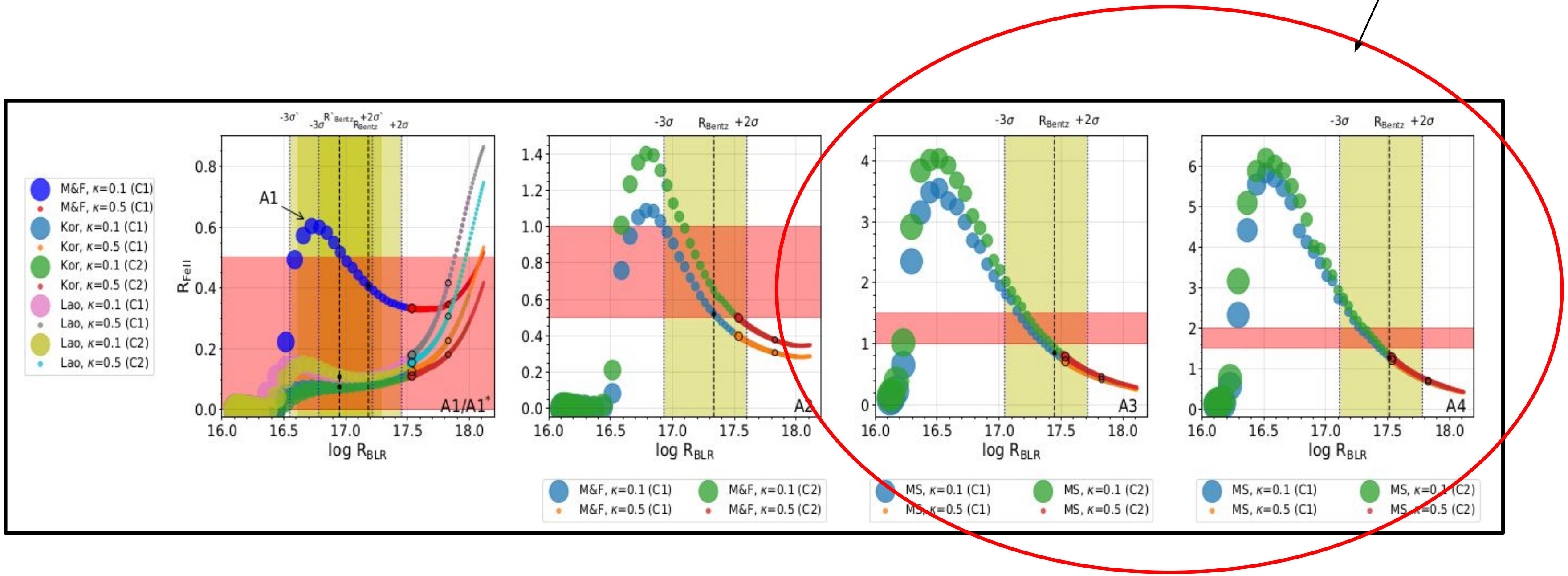


The Population A sources (with 'narrower' Hβ FWHM)

Panda et al. (2019b)

Effect of viewing angle (f-factor), physical trends

xA sources i.e. high FeII emitters

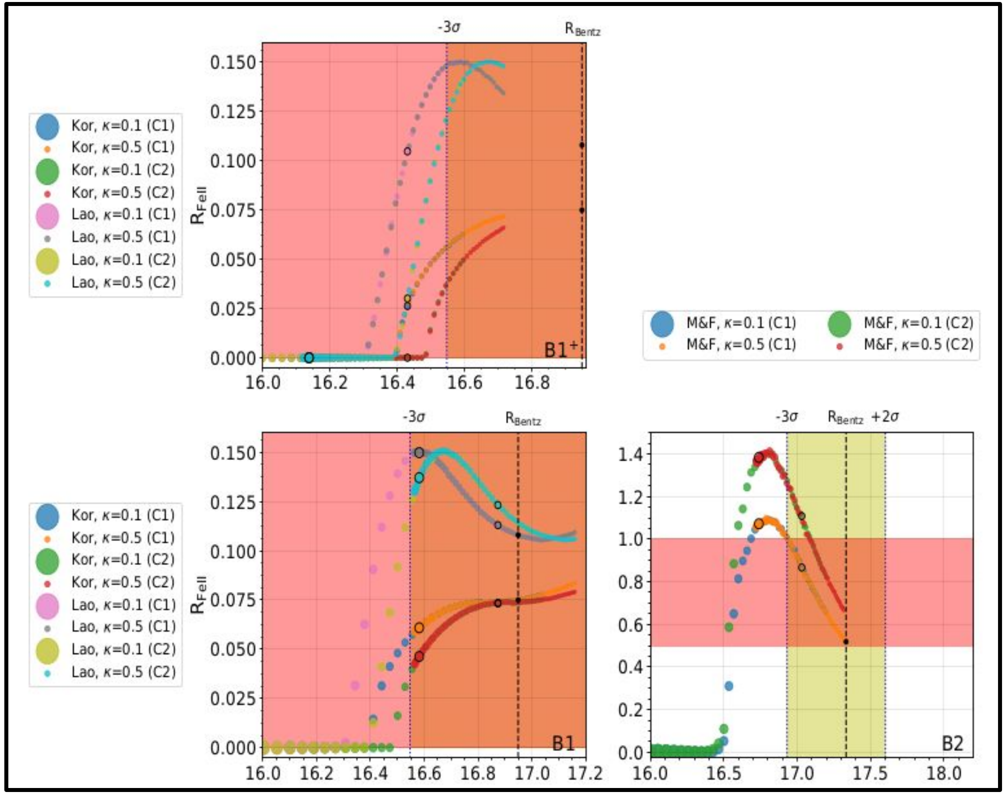


The Population A sources (with 'narrower' Hβ FWHM)

Panda et al. (2019b)

Effect of viewing angle (f-factor), physical trends

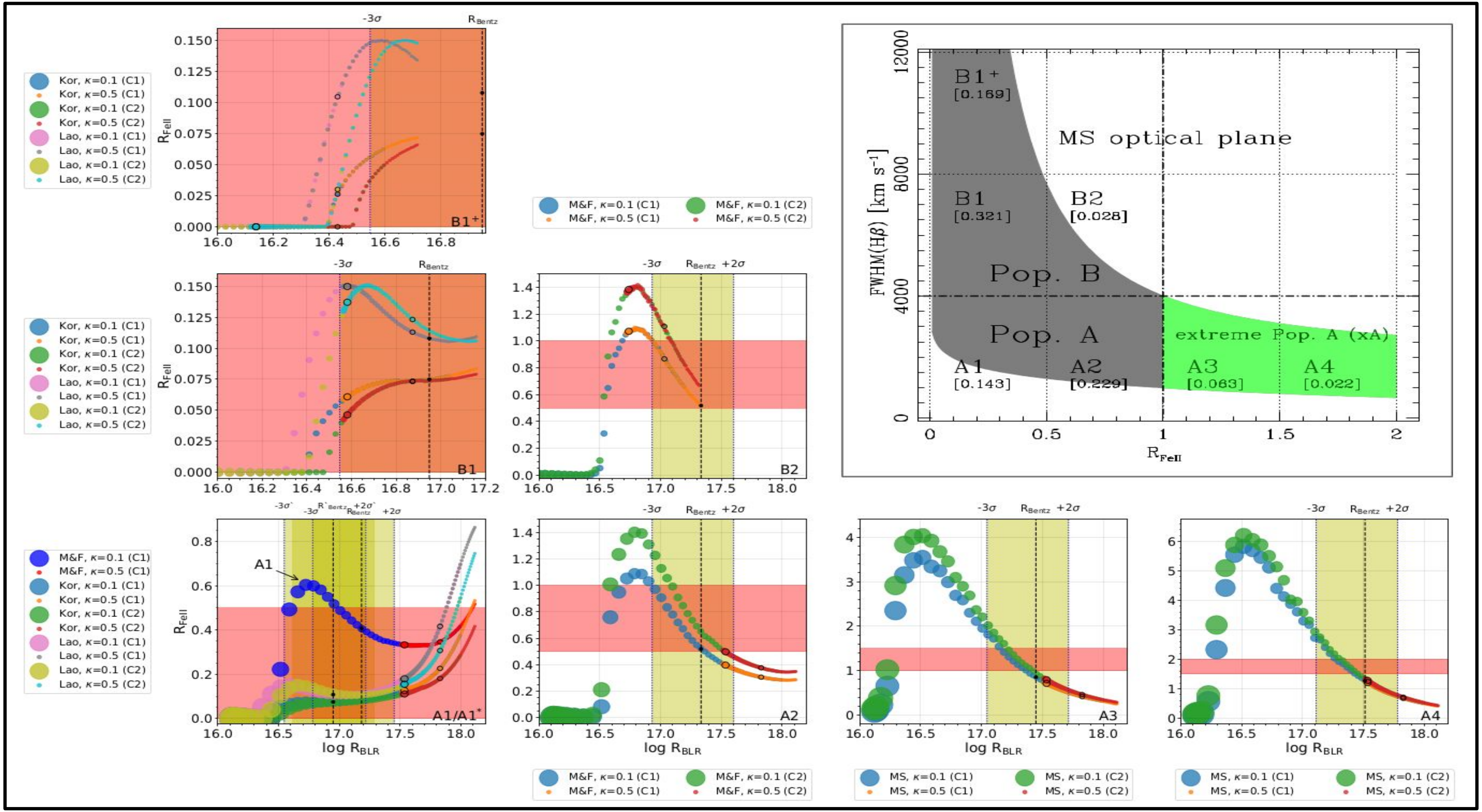
And the Population B sources
(with ‘broader’ Hβ FWHM)



Panda et al. (2019b)

Effect of viewing angle (*f*-factor), physical trends

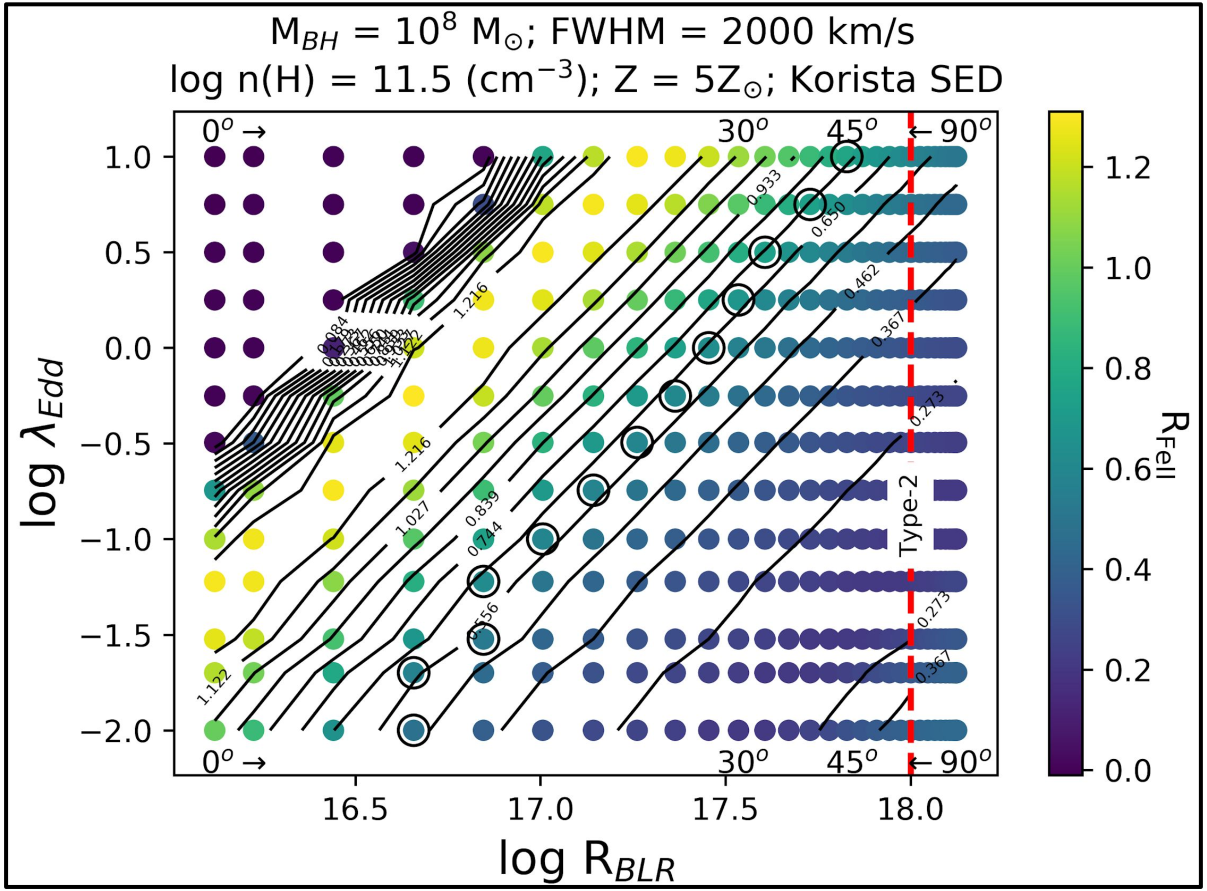
arXiv:1905.01729



Let’s make this more fun,
Shall we?

Higher $\lambda_{Edd} \leftrightarrow$ Shorter $R_{BLR} \leftrightarrow$ Higher FeII strength

Representative case showing the distribution of Eddington ratio vs size of the BLR as a function of the FeII strength (also shown by the contours). The plot is generated for input parameters for a "typical" xA source. The red dashed line marks the onset of the Type-2 sources (60°).



Panda et al. – in prep.

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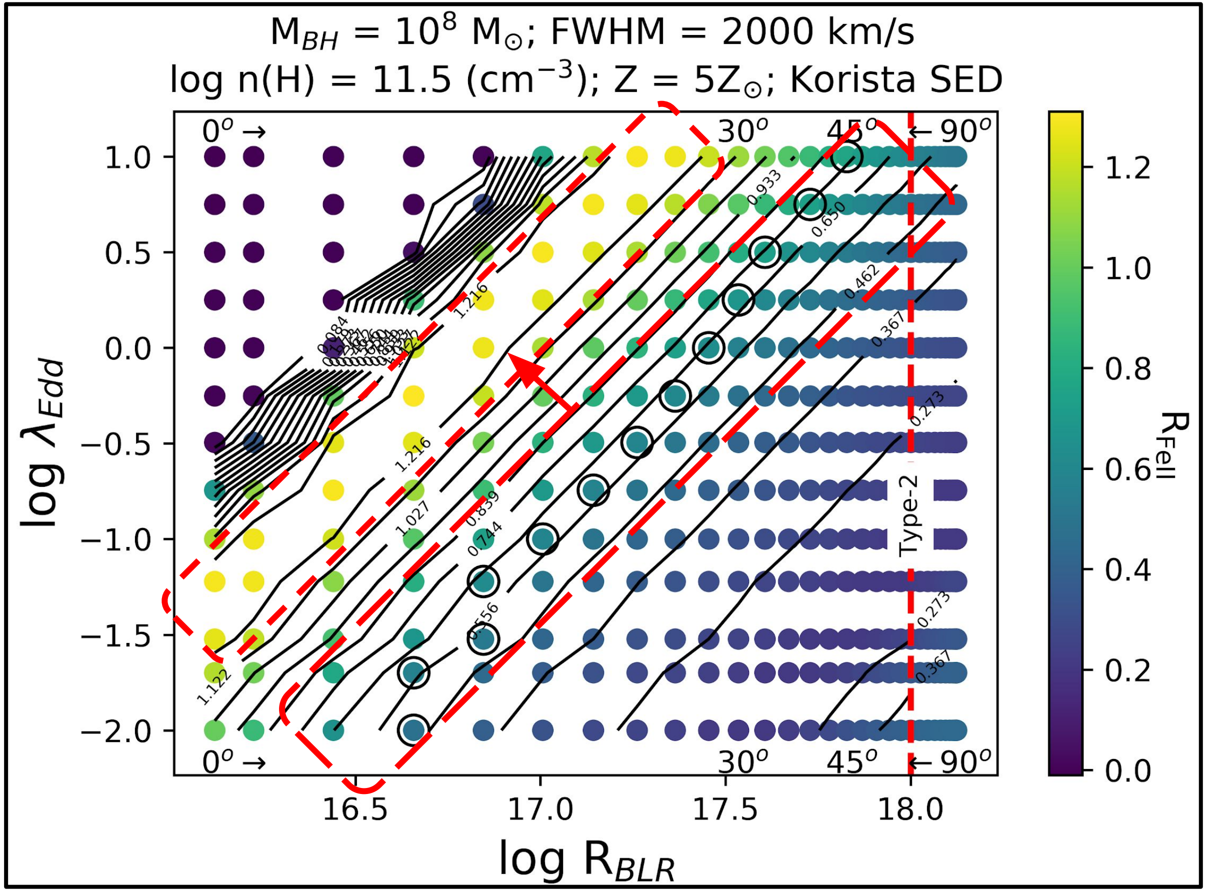
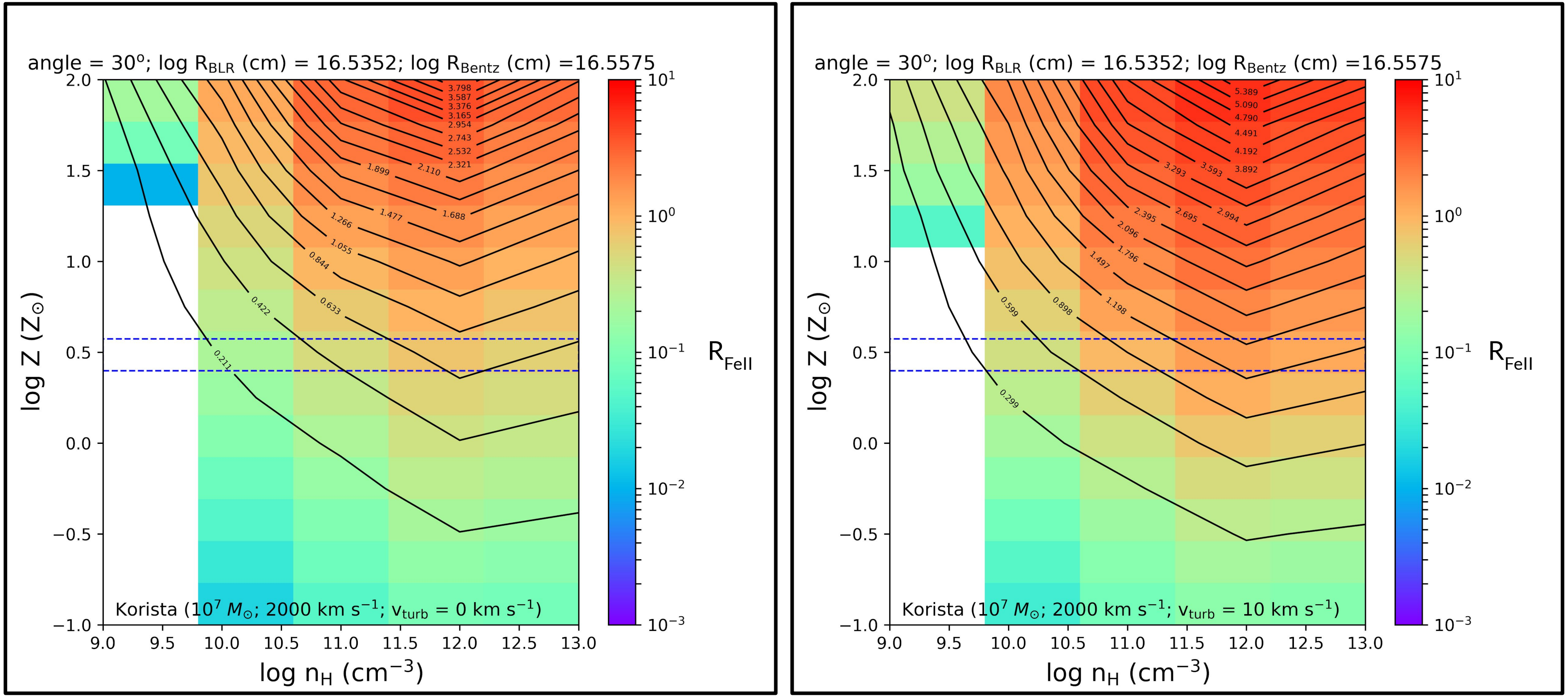
These results agree to our findings in Martínez-Aldama et al. (2019).



Panda et al. – in prep.

Testing with a ‘real’ source: *Mrk 335*



Constraining the viewing angle - ***Mrk335***: Metallicity - cloud density distribution as a function of R_{FeII} with turbulence (A) 0 km/s; (B) 10 km/s. The montage is shown for the best case inclination angle and the corresponding BLR size computed from the virial relation. The BLR size from the Bentz et al. 2013 *R-L* relation is shown for λ_{Edd}=0.33 and $M_{BH}=10^7\ M_\odot$.

Panda et al. – in prep.

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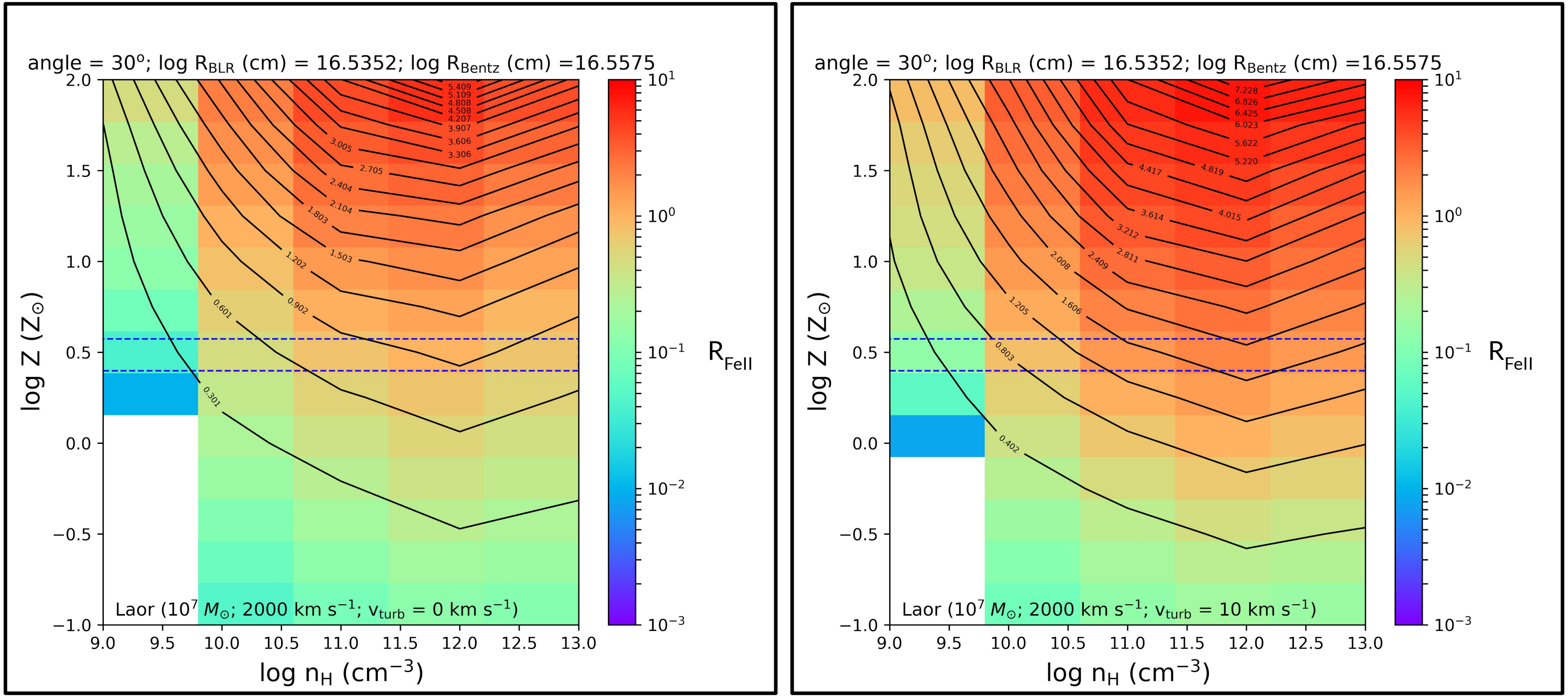

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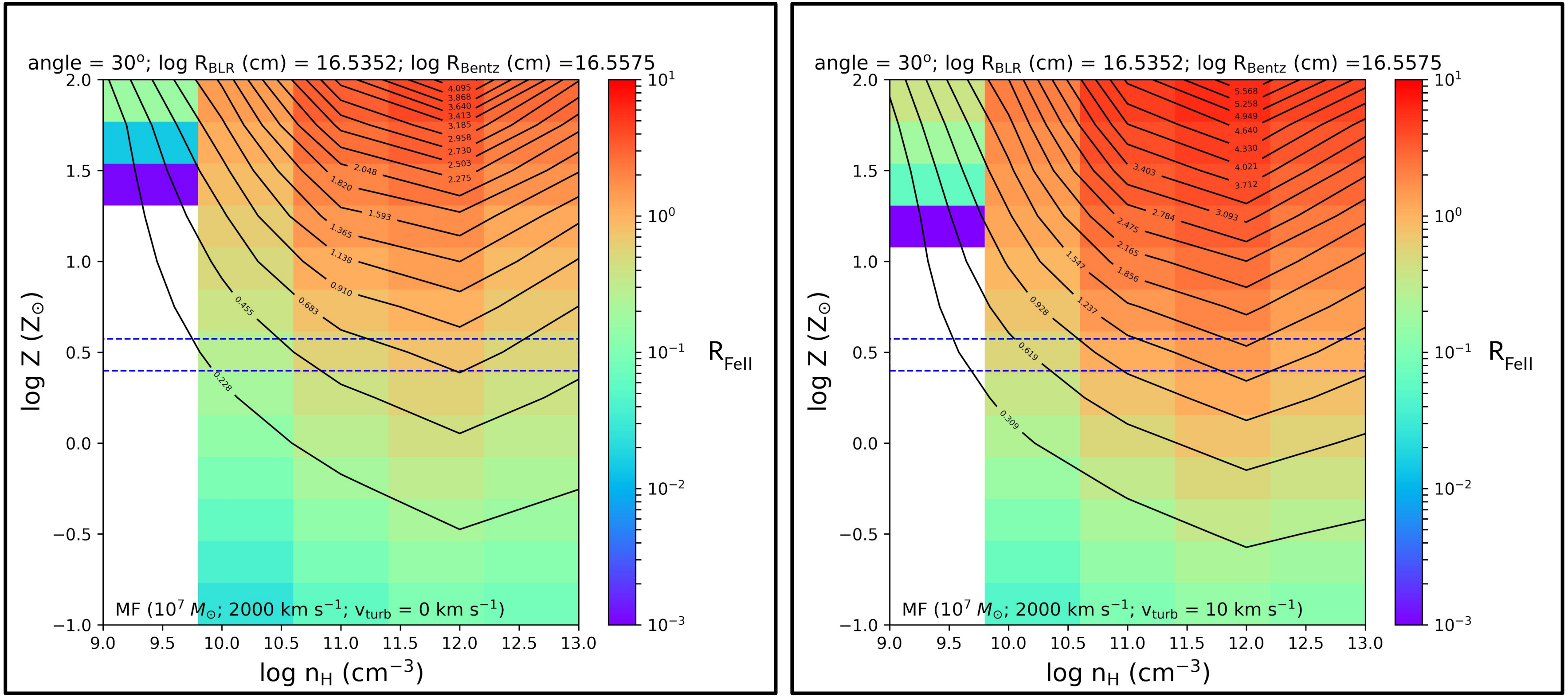

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Panda et al. – in prep.

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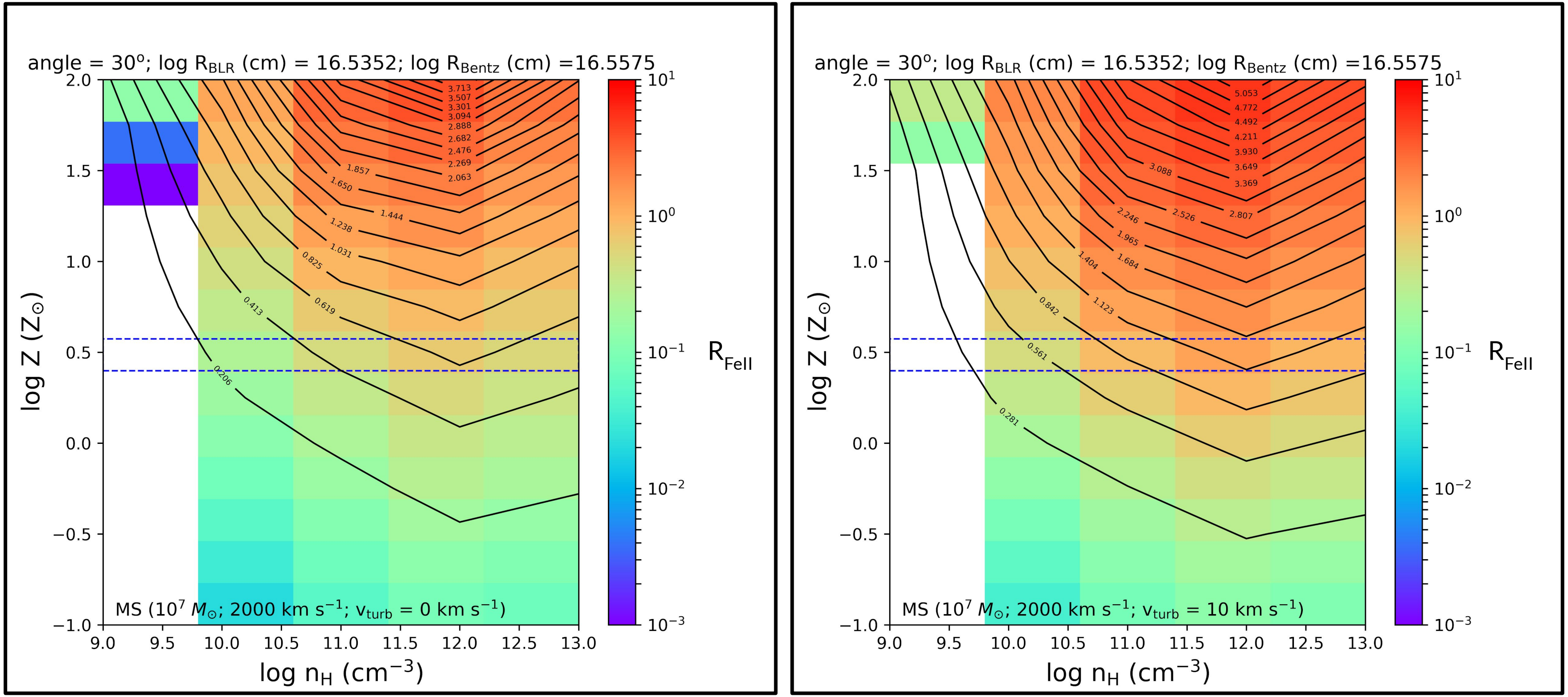

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Changing *** can be addressed as well - The answer is in the SED

Panda et al. - in prep.

Summary

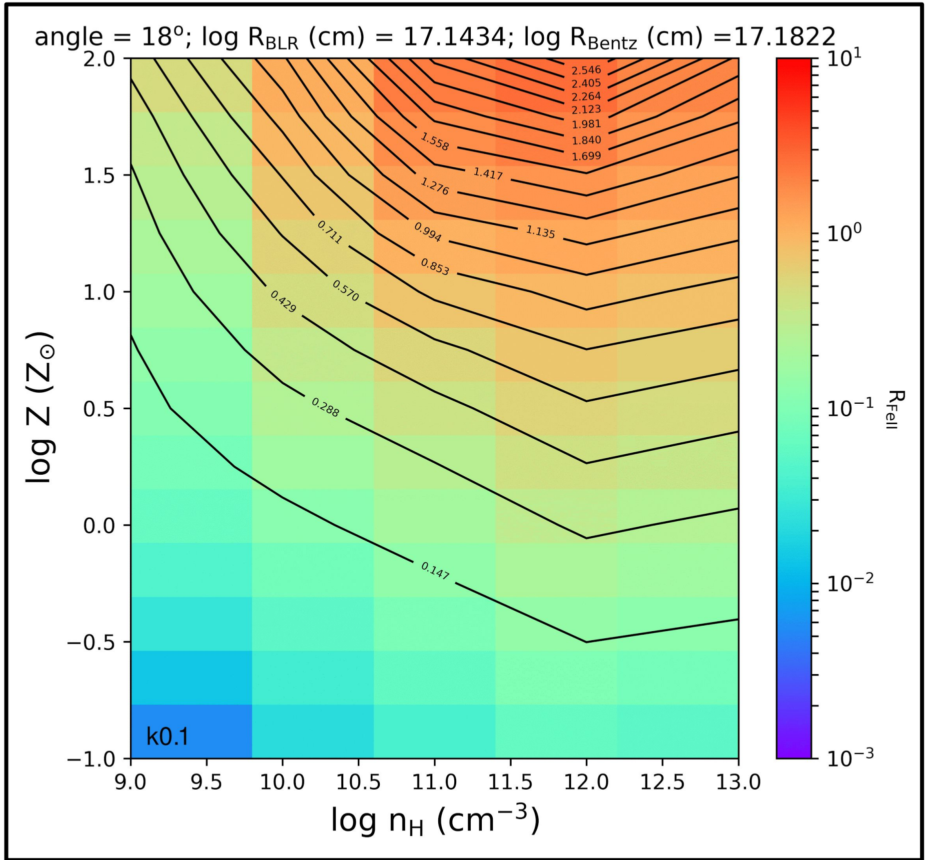
- The ‘entire’ quasar main sequence can be explained as a function of Eddington ratio, density, cloud composition and *viewing angle*.
- Our analyses explains the rarity of extreme FeII emitters and the use of xA sources as distance indicators in Cosmology.
- We further our model:
    - To understand the interplay between the physical quantities that drive the main sequence
    - To exploit this ‘full’ parameter space to constrain the *viewing angle* for real sources
    - This further allows us to check the validity of standard R_{BLR}–L_{5100} scaling relation esp. for extreme sources

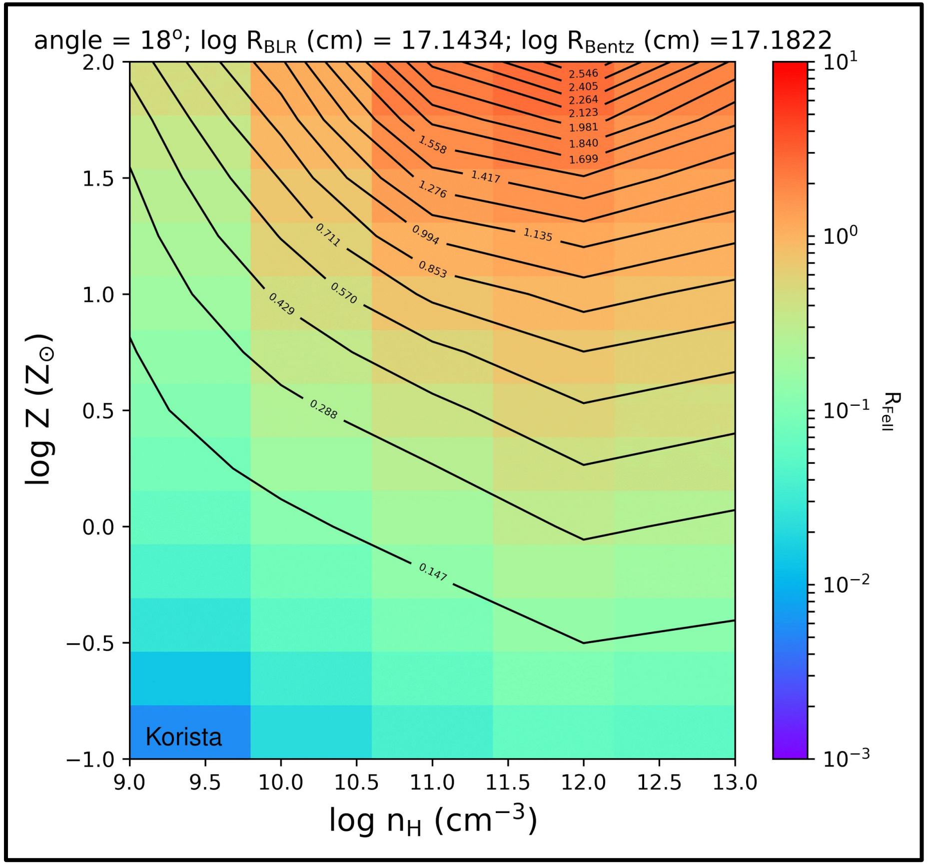
--x--

Exciting new results coming soon!

Multi-parameter space visualizations

M8 SED compare, A1 vturb 0



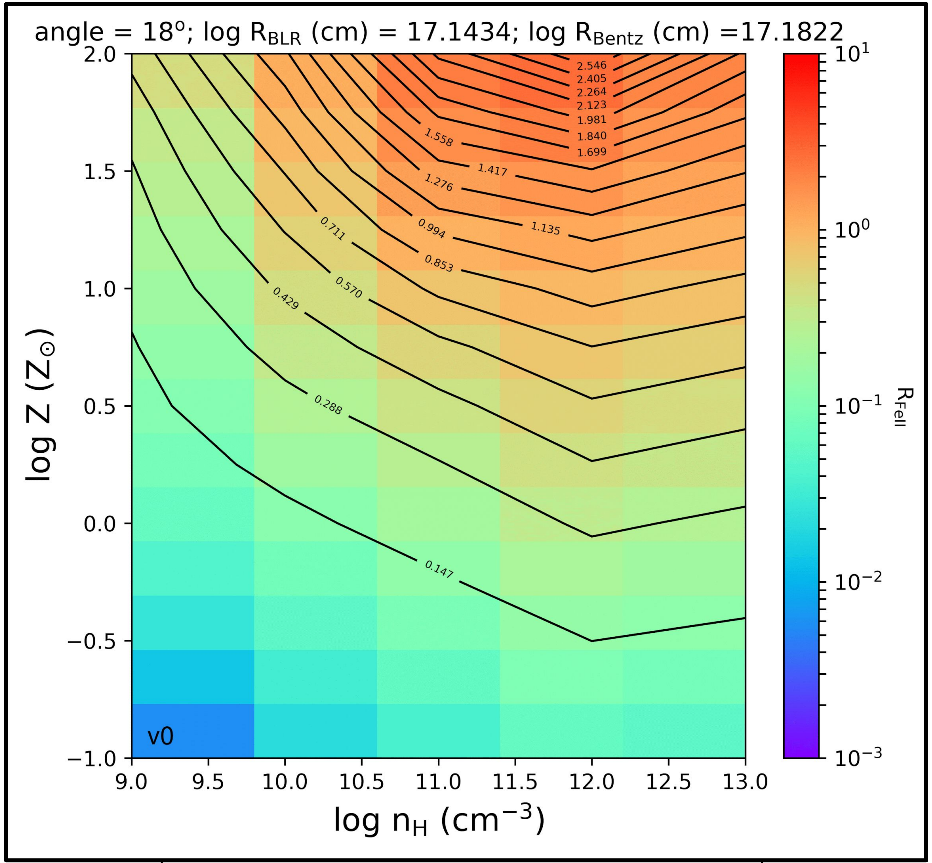


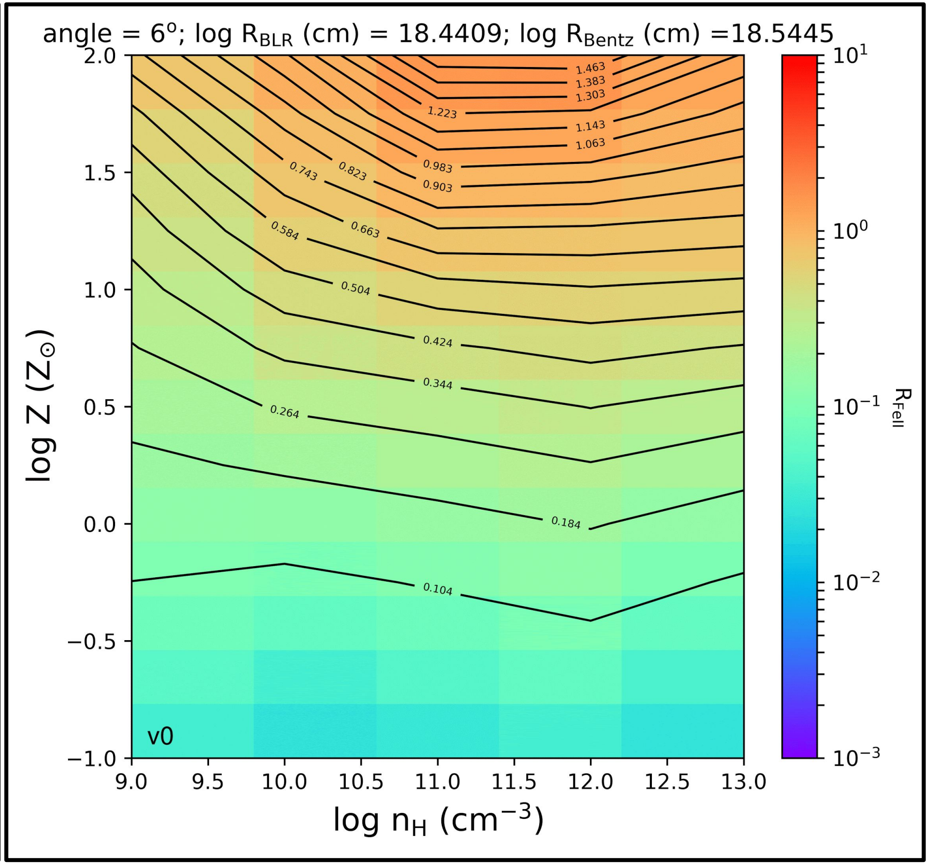
M8 k=0.1 vs k=0.5, Korista SED, Edd=0.2, A1

Panda et al. - in prep.

Multi-parameter space visualizations

M10 vturb 0, 10, 100, Kor, A1





M8 vturb 0, 10, 100, Kor, A1

Panda et al. - in prep.