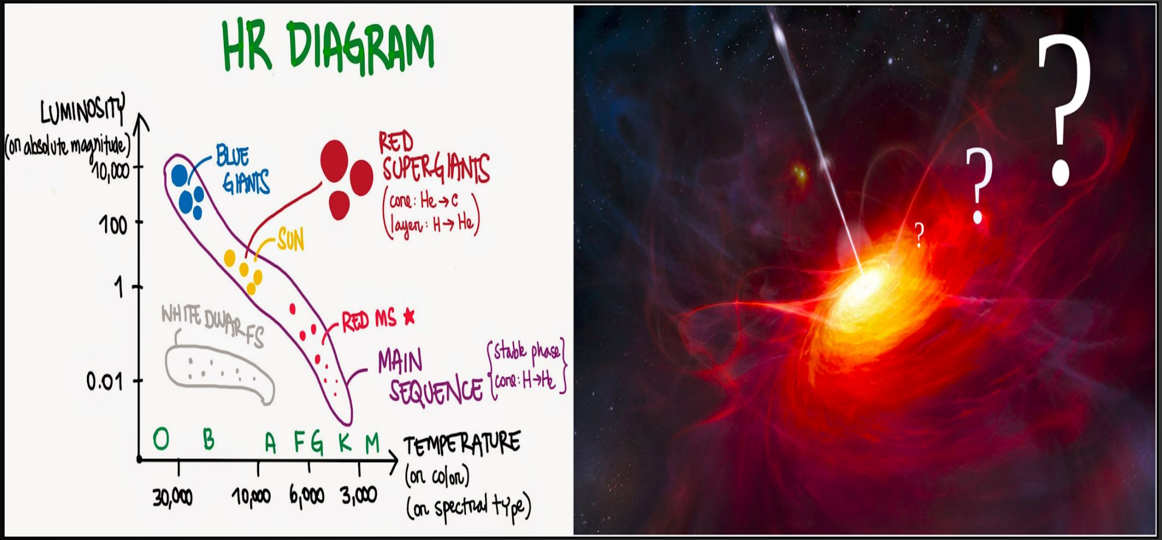
Decoding the **FeII emission** in the context of **Quasar Main Sequence**

Swayamtrupta Panda

Center for Theoretical Physics / Nicolaus Copernicus Astronomical Center, Warsaw

Supervisor: Prof. Bożena Czerny

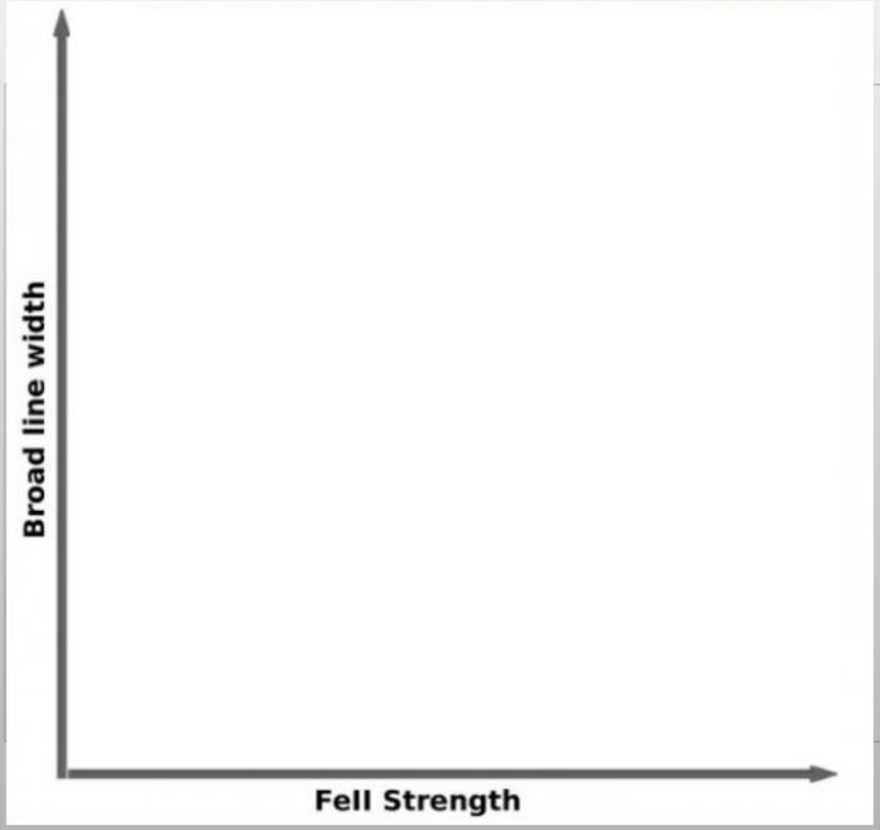
What motivates us?

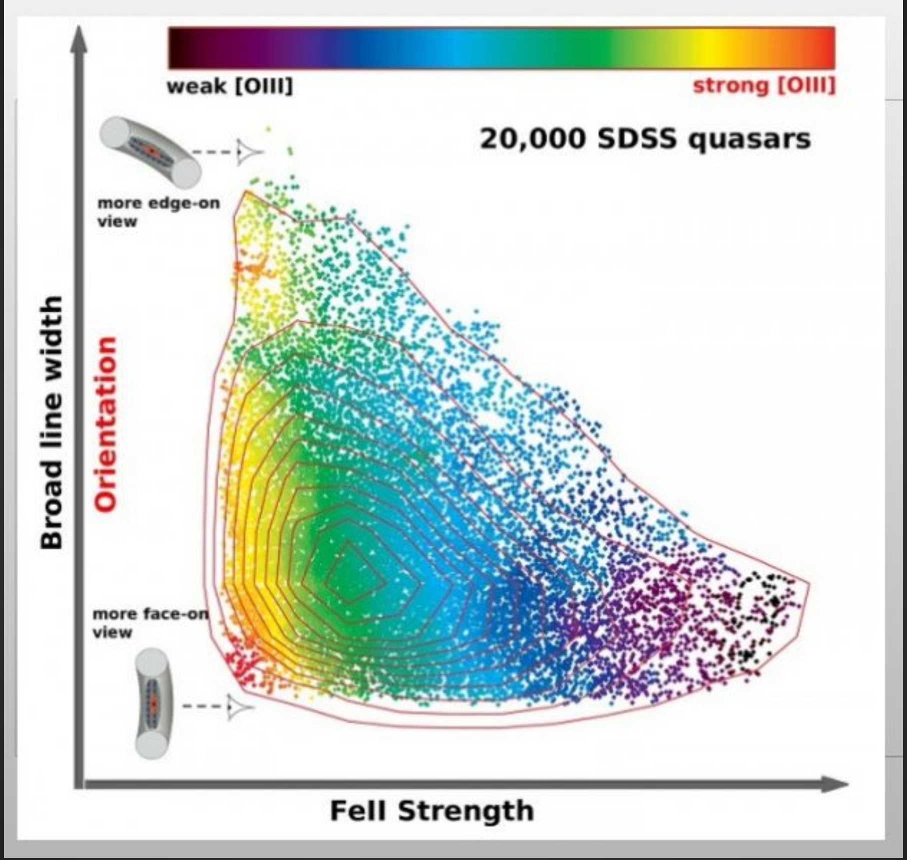


In search for an equally robust scheme for studying the sequencing in quasars:

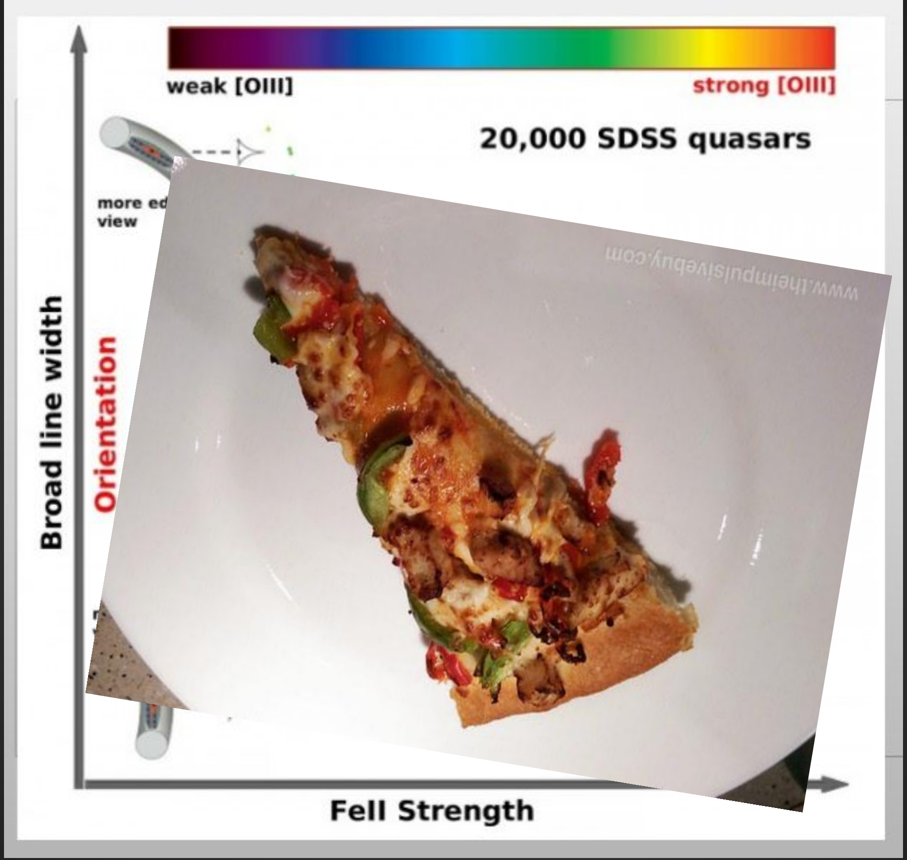
"An extension of the H-R diagram?"

How to make a
Quasar Main Sequence ?


Broad line width
Fell Strength



weak [OIII]
strong [OIII]
20,000 SDSS quasars
more edge-on view
more face-on view
Broad line width
Orientation
FeII Strength


weak [OIII]
strong [OIII]
20,000 SDSS quasars
more ed
view
Broad line width
Orientation
Fell Strength
www.theimpulsivebuy.com

EV1: Anticorrelation between FeII–[OIII] (r = -0.670)

Principal Component Analysis with 13 observables from quasar spectra

FROM HERE

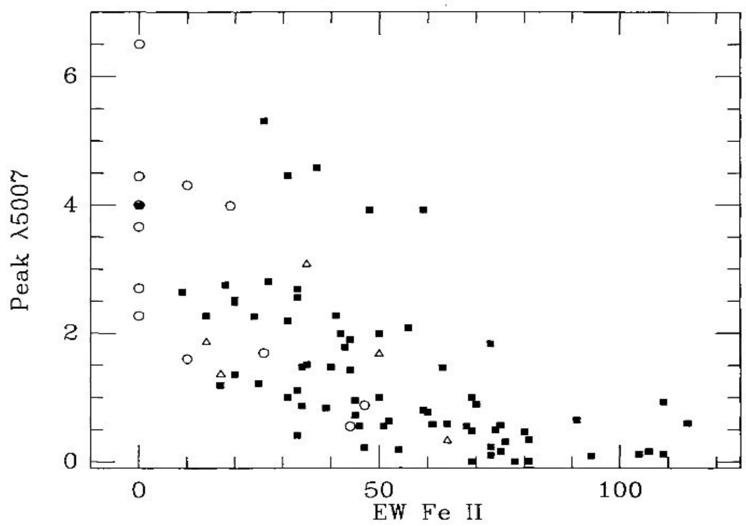


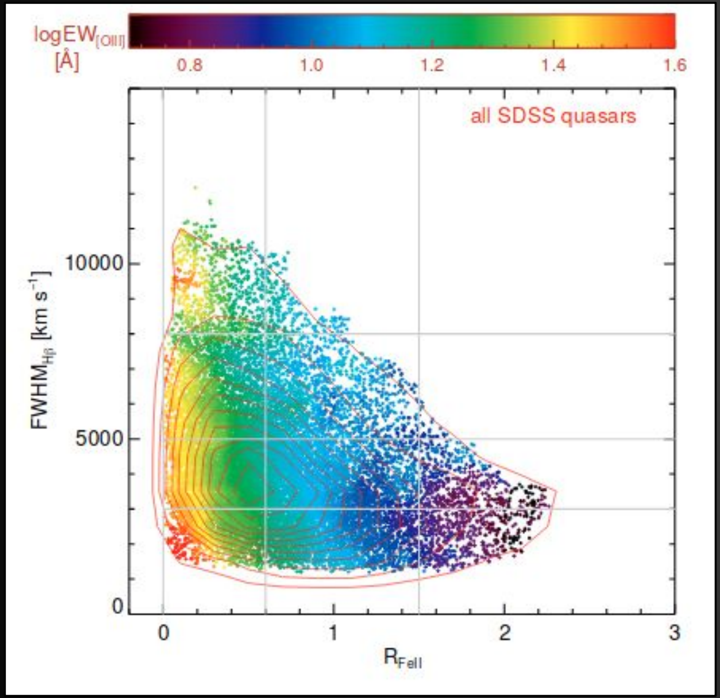
FIG. 2.—Ratio of peak height of [O III] λ5007 to that of Hβ plotted against equivalent width of the Fe II emission between λ4434 and λ4684. Solid squares are radio-quiet objects, open circles are steep-spectrum radio sources, and open triangles are flat-spectrum radio sources.

- The other Eigenvectors
  - EV2: Luminosity Dependence of HeII λ4686
  - EV3: EW Hβ
  - EV4: Hβ shape
  - EV5: Hβ shift

Boroson & Green, 1992

PASSING BY

The Quasar Main Sequence diagram



1. **"Our results show that most of the diversity of quasar phenomenology can be unified with two simple quantities, Eddington ratio and orientation"**.
2. "the range of FWHMHβ at fixed R_{FeII} includes a substantial component due to orientation effects such that more edge-on systems have on average larger FWHMHβ , indicating a flattened BLR geometry".
3. "Higher-Eddington ratio quasars (with higher RFeII) may drive stronger outflows in both the broad-line region and the narrow-line region".

Distribution of quasars in the EV1 plane. The horizontal axis is the relative FeII strength, R_{FeII}, and the vertical axis is the broad Hβ FWHM. The red contours show the distribution of their SDSS quasar sample, and the points show individual objects. They color-code the points by the [OIII] λ5007 strength, averaged over all nearby objects in a smoothing box of ΔR_{FeII}= 0.2 and ΔFWHMHβ= 1000 km s−1. The EV1 sequence is the systematic trend of decreasing [OIII] strength with increasing R_{FeII}. The gray grid divides this plane into bins of $FWHM_{H\beta}$ and R_{FeII}, in which they study the stacked spectral properties

Shen & Ho, 2014

The Standard Accretion Disk

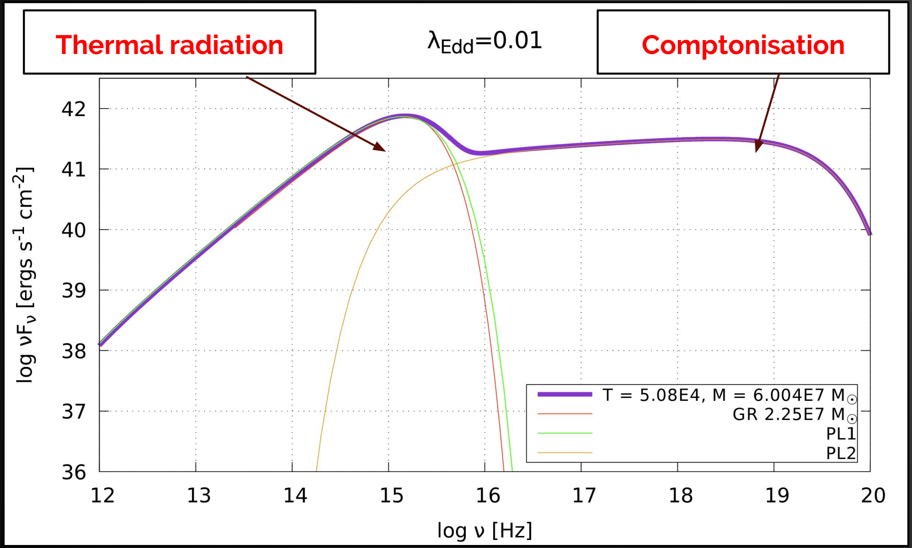
+

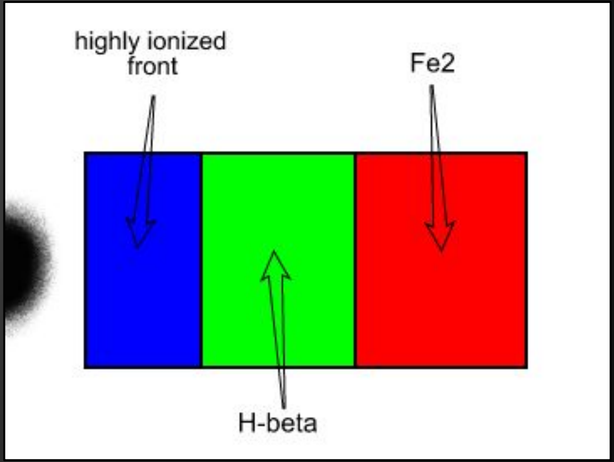
Hot Comptonization

From Theoretical Standpoint...

- SED modelled with 2 power laws
- Peak of the Big Blue Bump in a multicolor accretion disk
- Constant Density single cloud model
- Photoionization modelling (CLOUDY)

$$T_{max} = \left[\frac{3GM\dot{M}}{8\pi\sigma r^3}\left(1-\sqrt{\frac{R_{in}}{r}}\right)\right]^{0.25} = 2.034 \times 10^{19}\left(\frac{\dot{M}}{M^2}\right)^{0.25}$$



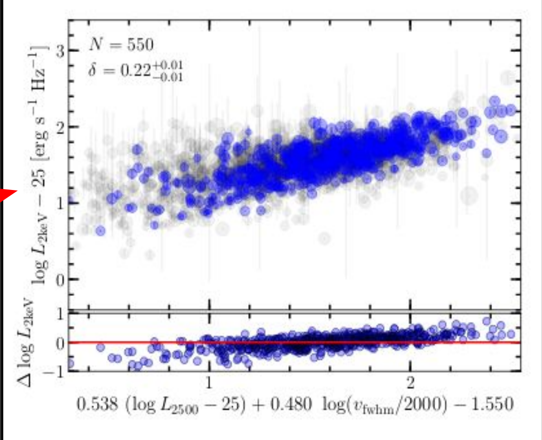


Panda et al. 2018b, ApJ 866 115

From Theoretical Standpoint…

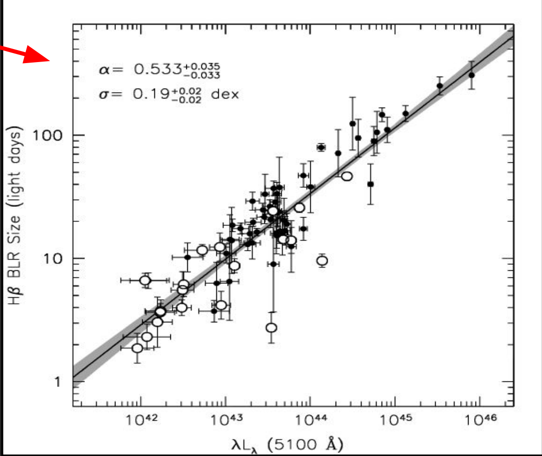
The relative normalization of the X-ray component with respect to UV is found from the universal scaling law recently discovered by Lusso & Risaliti (2017):

$$\log L_X = 0.610 \log L_{UV} + 0.538 \log v_{FWHM} + 3.40$$



Distance to the Broad-line region (Bentz et al. 2013):

$$\log R_{BLR} = 1.555 + 0.542 \log L_{44,5100} \text{ [light days]}$$



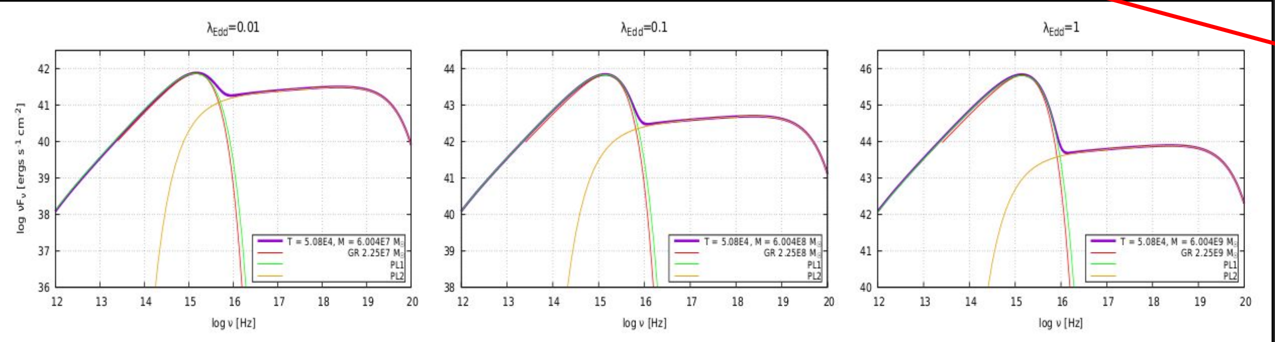
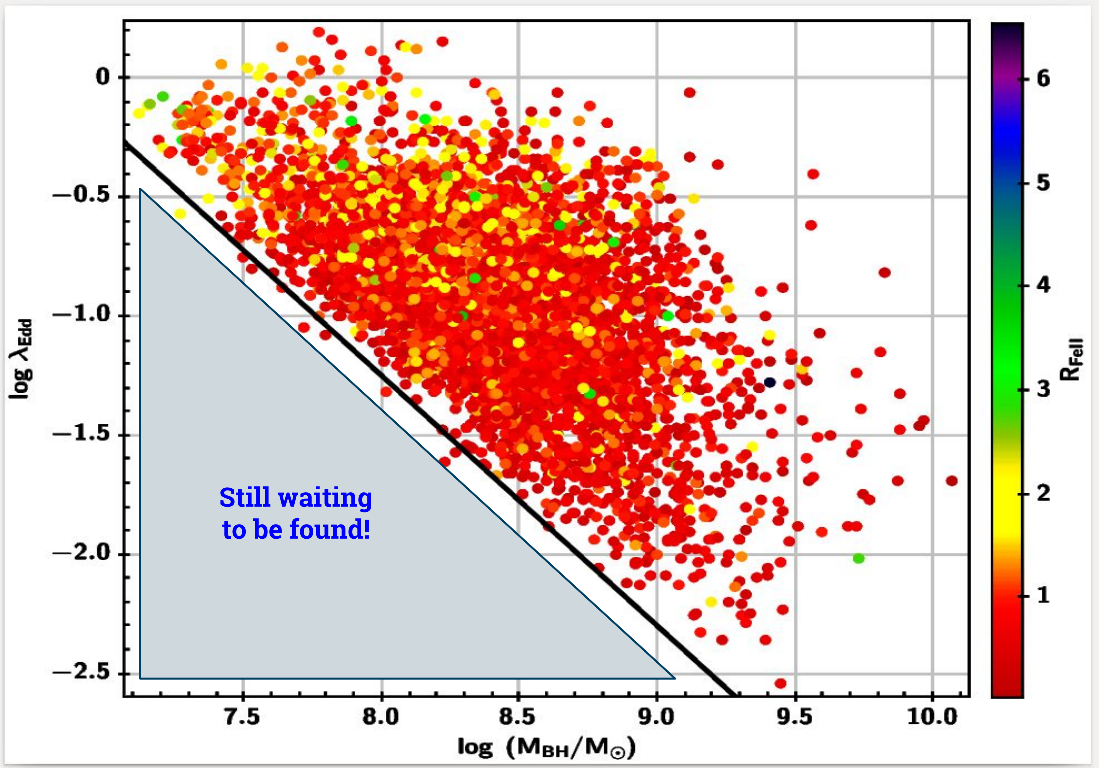


Figure 1. Three examples of the incident continuum used in our computations: Big Blue Bump (green line: PL1) for $T_{max} = 5.08 \times 10^4$ K and three values of the Eddington ratio, which correspond to three values of the black hole mass (from left to right) $6 \times 10^7 M_\odot$, $6 \times 10^8 M_\odot$, and $6 \times 10^9 M_\odot$. The orange line (PL2) corresponds to the hard X-ray emission. The overall shape of the SED is given by the purple line. The red line corresponds to the classical model inclusive of the effects from GR.

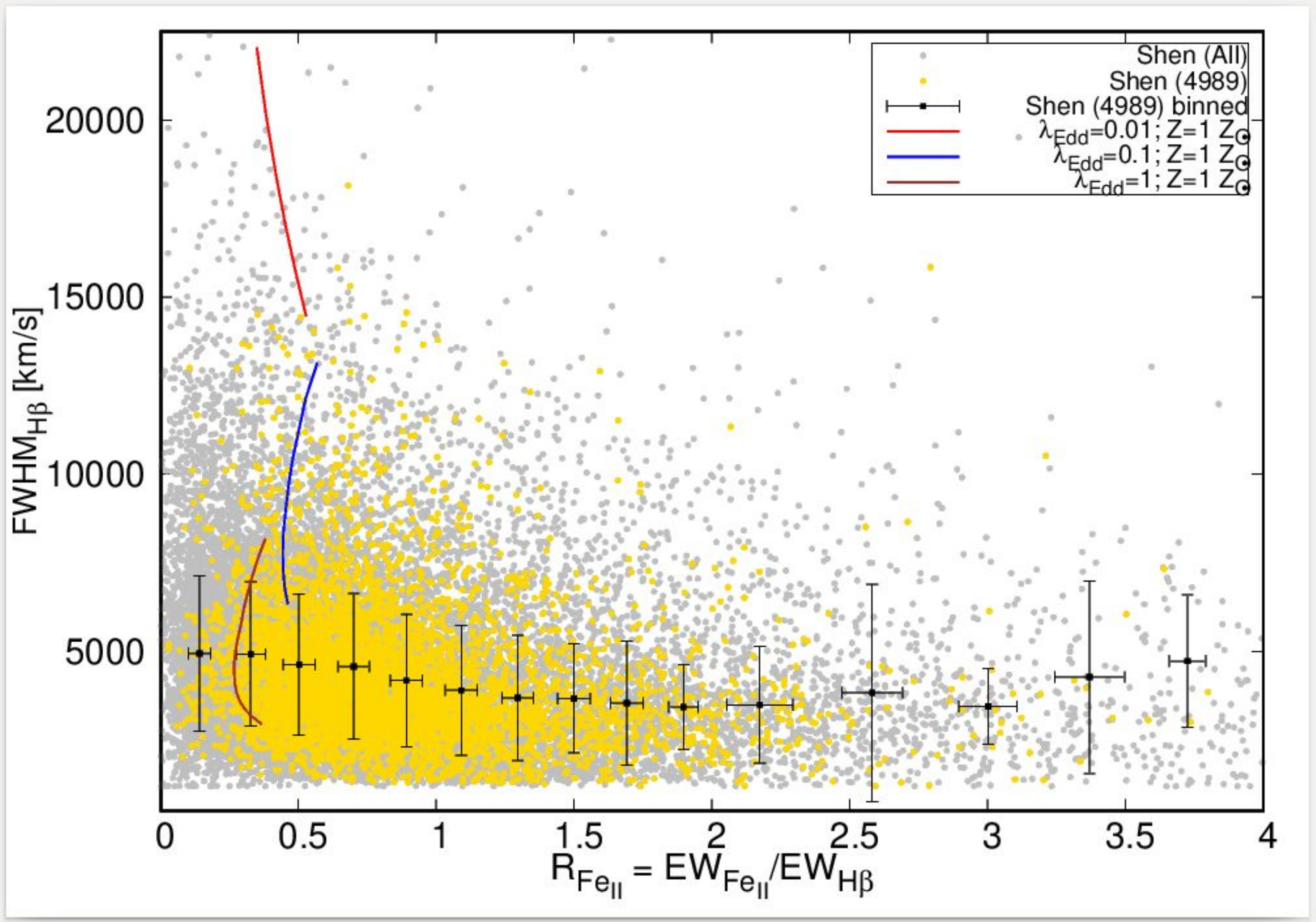
Panda et al. 2018b, ApJ 866 115

λ_{Edd} - M_{BH} limits from observations

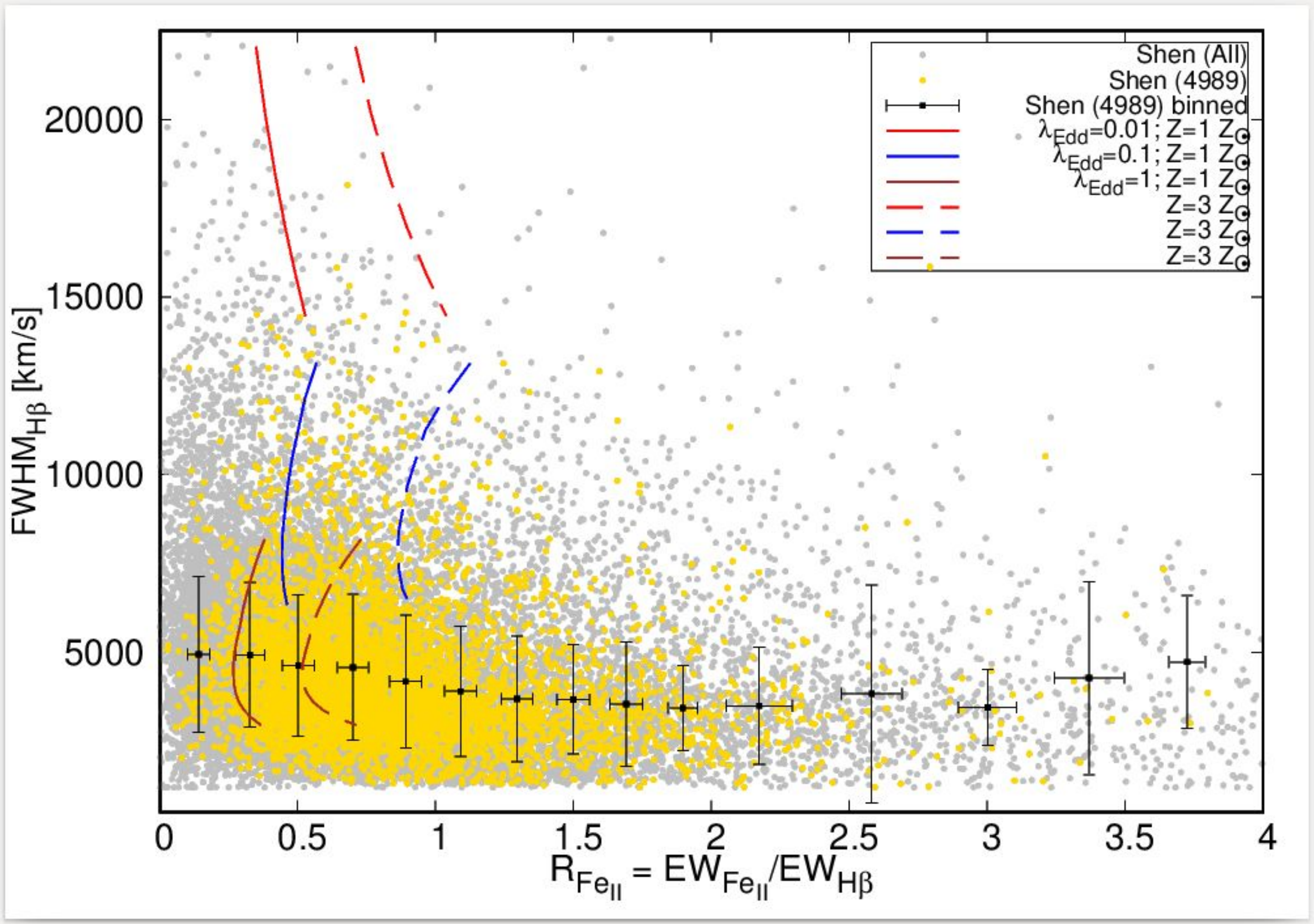


- Sample selection matters
- Biased towards higher L_{bol}/L_{Edd} and higher M_{BH}
- Need for more observations

Panda et al. 2018b, ApJ 866 115

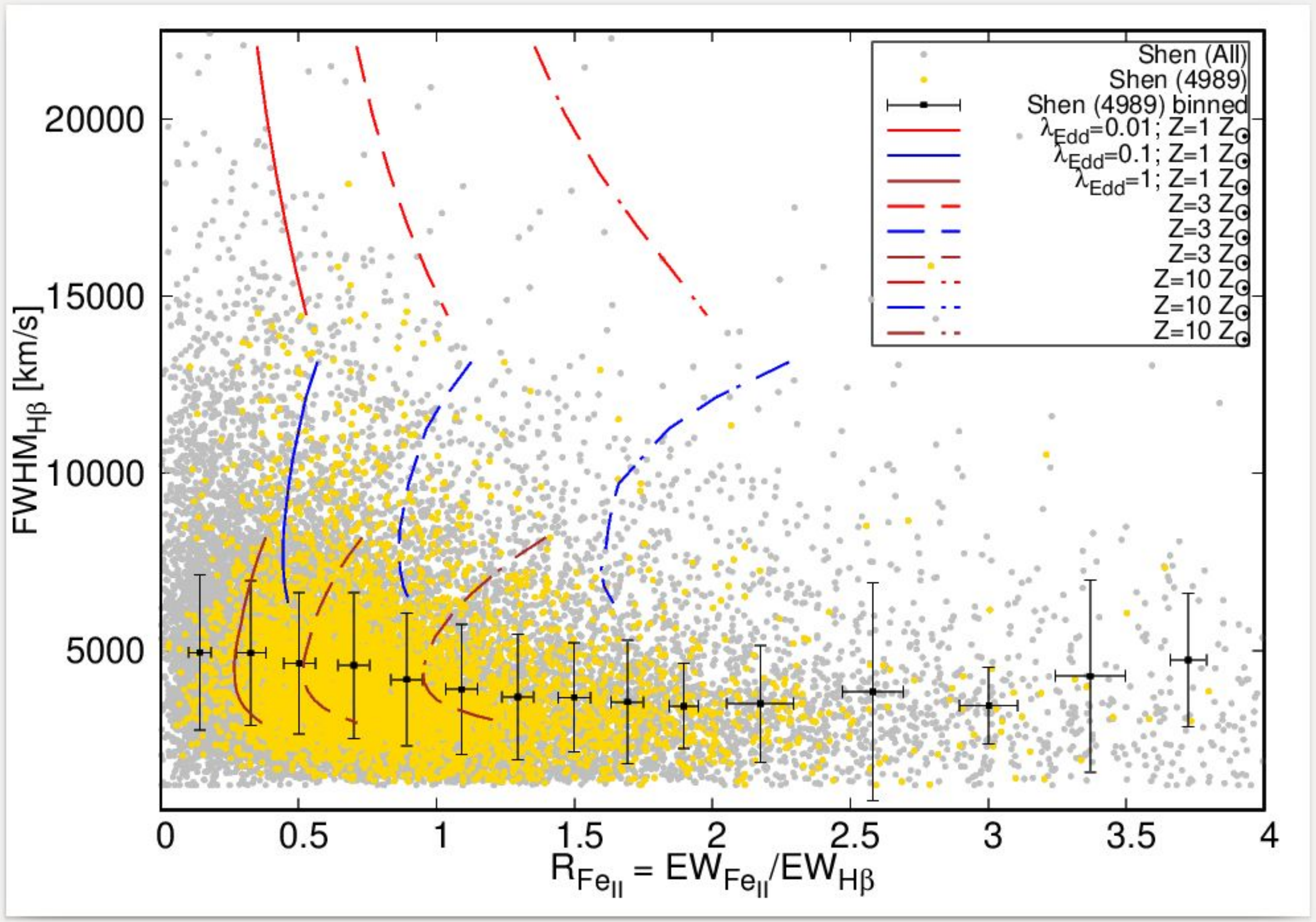

Shen (All)
Shen (4989)
Shen (4989) binned
λEdd=0.01; Z=1 Z⊙
λEdd=0.1; Z=1 Z⊙
λEdd=1; Z=1 Z⊙
FWHMHβ [km/s]
20000
15000
10000
5000
0
0.5
1
1.5
2
2.5
3
3.5
4
RFeII = EWFeII/EWHβ

STEP 1

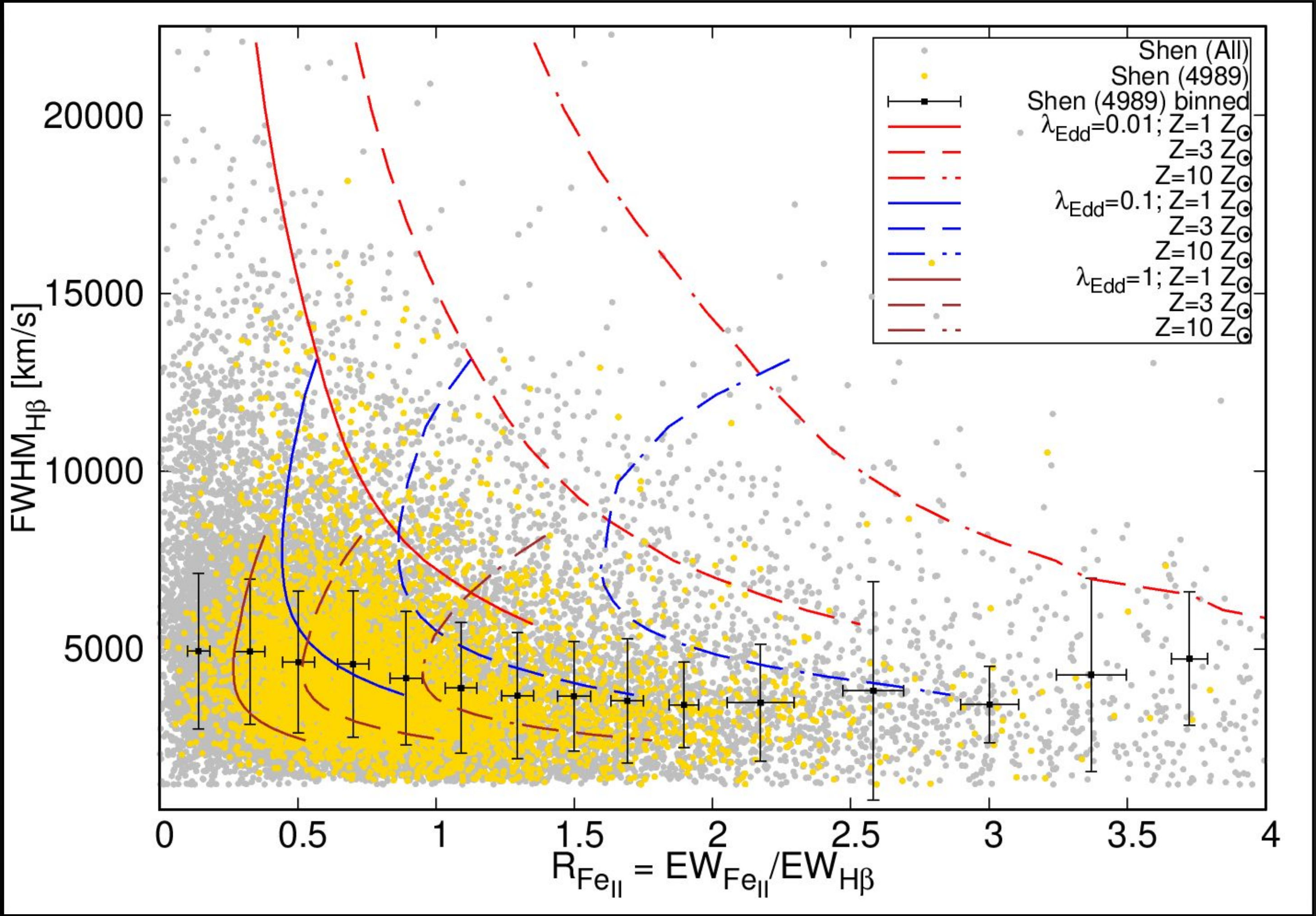

Shen (All)
Shen (4989)
Shen (4989) binned
λ_{Edd}=0.01; Z=1 $Z_\odot$
λ_{Edd}=0.1; Z=1 $Z_\odot$
λ_{Edd}=1; Z=1 $Z_\odot$
Z=3 $Z_\odot$
Z=3 $Z_\odot$
Z=3 $Z_\odot$
$FWHM_{H\beta}$ [km/s]
20000
15000
10000
5000
0
0.5
1
1.5
2
2.5
3
3.5
4
$R_{Fe_{II}} = EW_{Fe_{II}}/EW_{H\beta}$

STEP 2

STEP 3



Panda et al. 2018b, ApJ 866 115



TO HERE

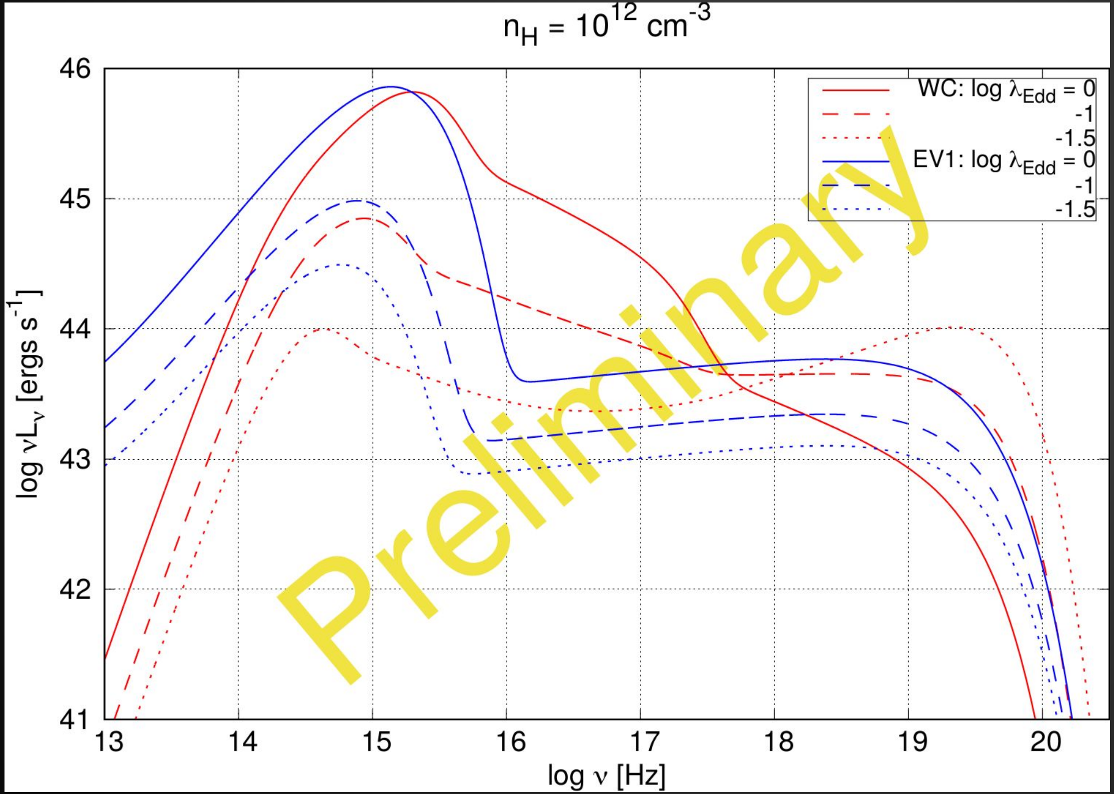
No single simple driver of the quasar main sequence

Panda et al. 2018b, ApJ 866 115

The need to push further…
Where is that extra FeII hidden?

Hunting down its origin(s)

Testing with a Warm Corona Model

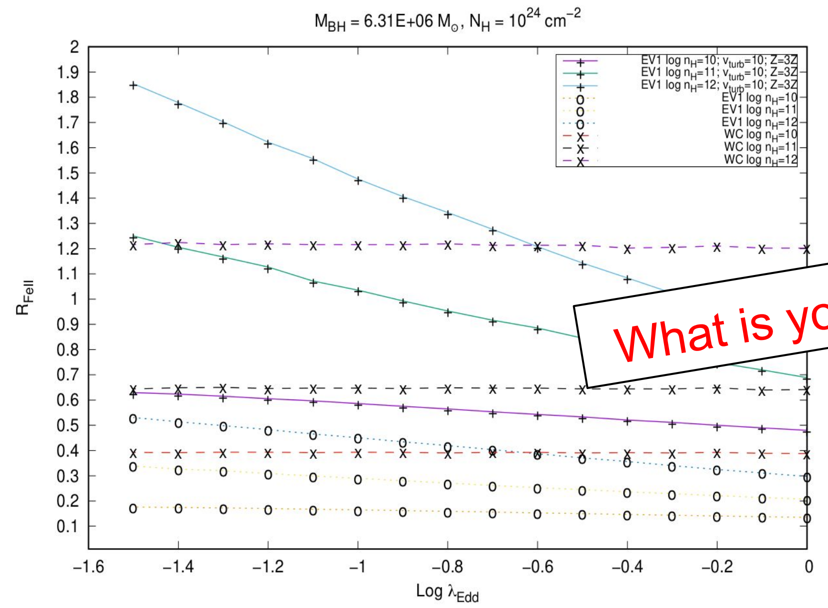


- The additional power law (in the **XUV** and soft X-rays) in theory, should enhance the net optical FeII production.
- Shift due to color-temperature correction
- $FeII_{WC}$ > $FeII_{initial}$
- But, $FeII_{WC}$ < $FeII_{current}$

(integrated from 4434-4684 Å)

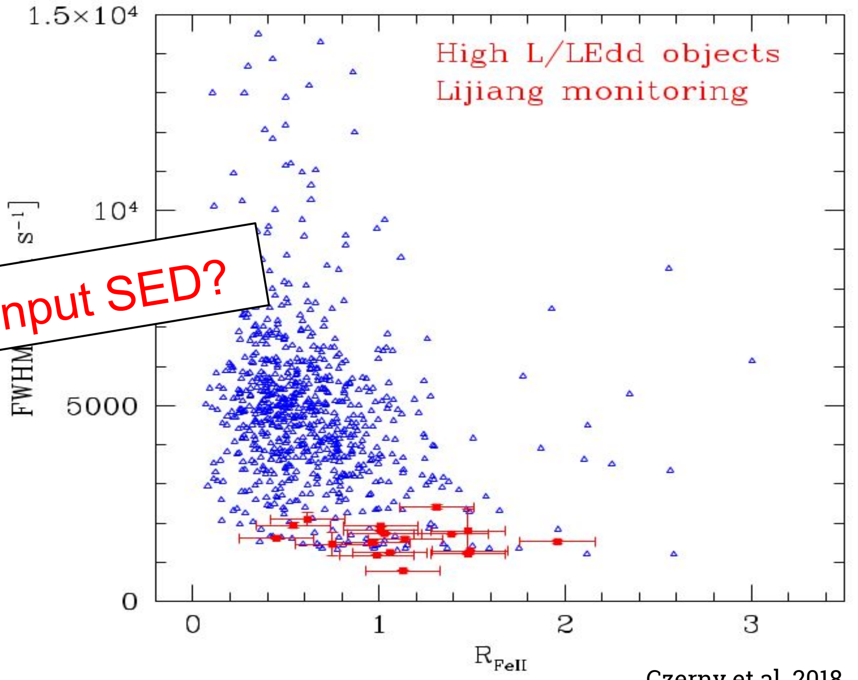
Panda et al. (in prep)

(IN)dependency of Eddington Ratio on FeII strength



Panda et al. (in prep)

What is your input SED?



Czerny et al. 2018

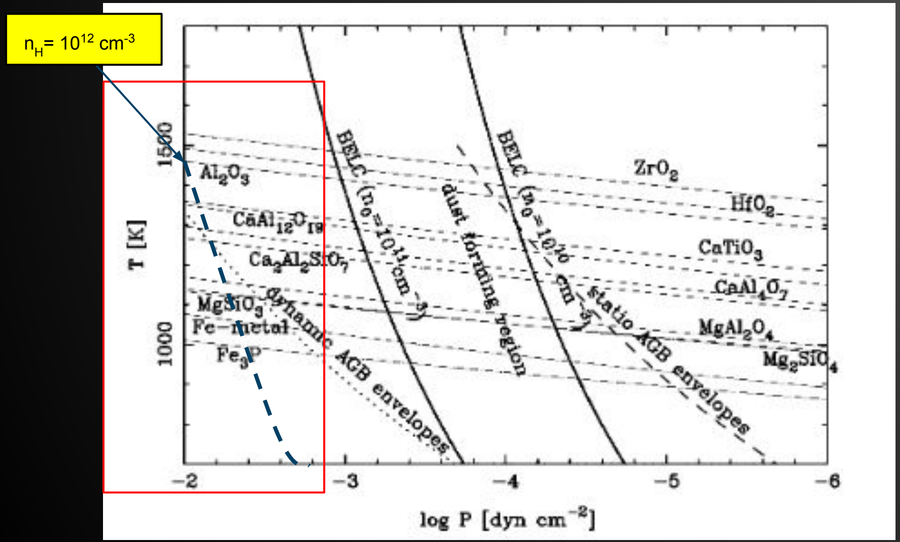
Photoionisation Simulations

Recent Observations

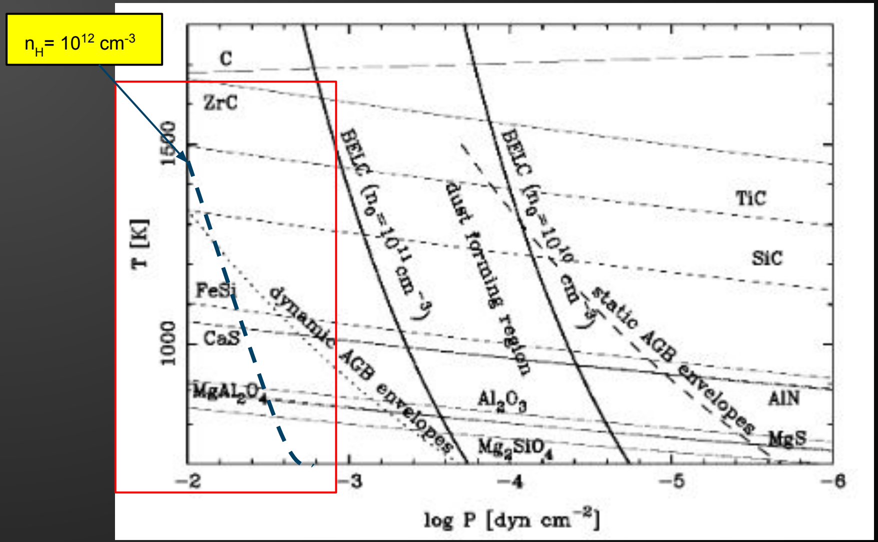
Revisiting the past: the AGN-AGB connection and its role in FeII enhancement

- Dust formation window: Effective dust condensation occurs with a chemically enriched medium that has a sufficiently low temperature, and a large enough density
- Importance of timescale on the grain-size, net amount of dust produced and overall chemical composition

O-rich



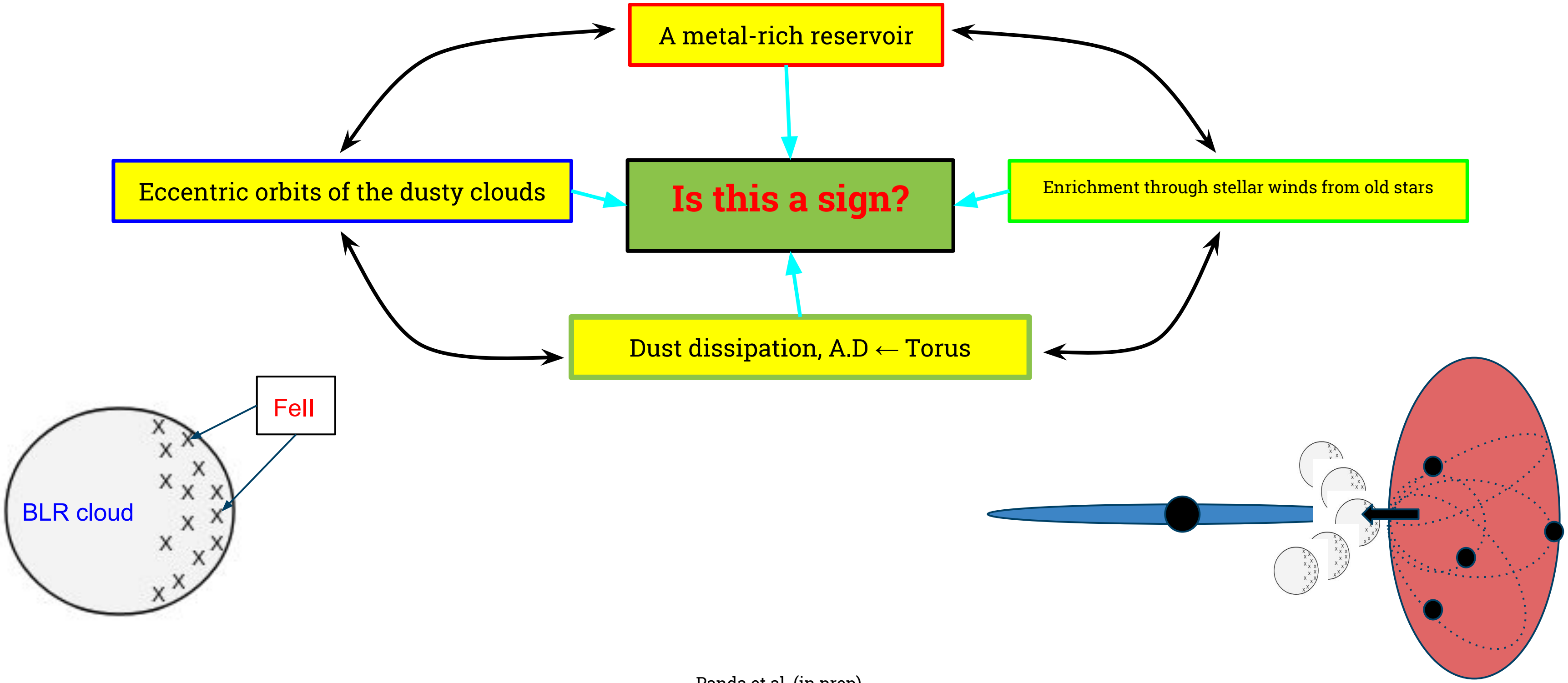
C-rich



Elvis et al. 2002

The Connection…that is yet to be made

An idea for `FeII replenishment’



Panda et al. (in prep)


Which came first?
Pizza
or the
Quasar Main Sequence