



# Systematic Collapse of the Accretion Disc Across the Supermassive Black Hole Population

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Japan Society for the Promotion of Science  
(JSPS)

First Results from the SRG/eROSITA  
All-Sky Survey  
Garching, 16.09.2024

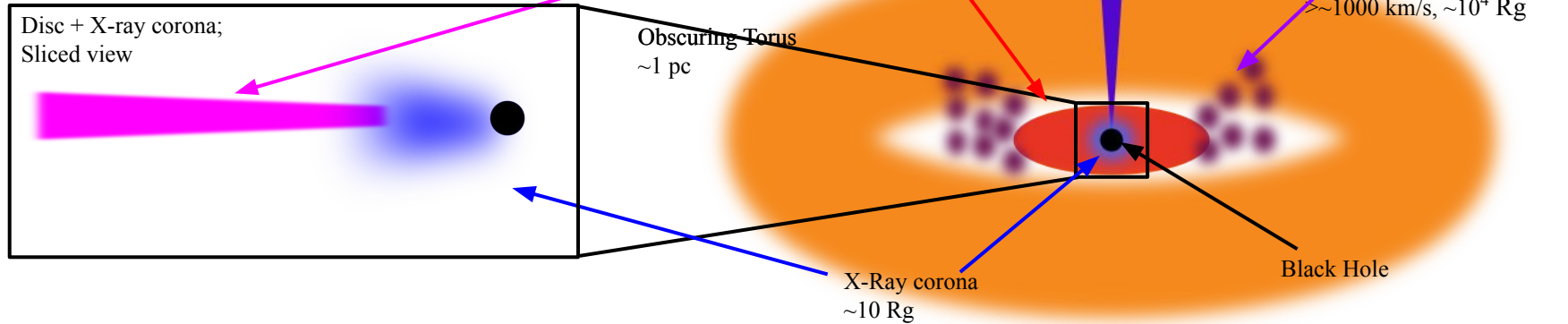
# Overview

Eddington ratio - will be used throughout

$$R_G = \frac{GM}{c^2}$$

$$\dot{m} = \dot{M}/\dot{M}_{\text{Edd}} = L/L_{\text{Edd}}$$

$$L_{\text{Edd}} = \frac{4\pi GMcm_p}{\sigma_T}$$

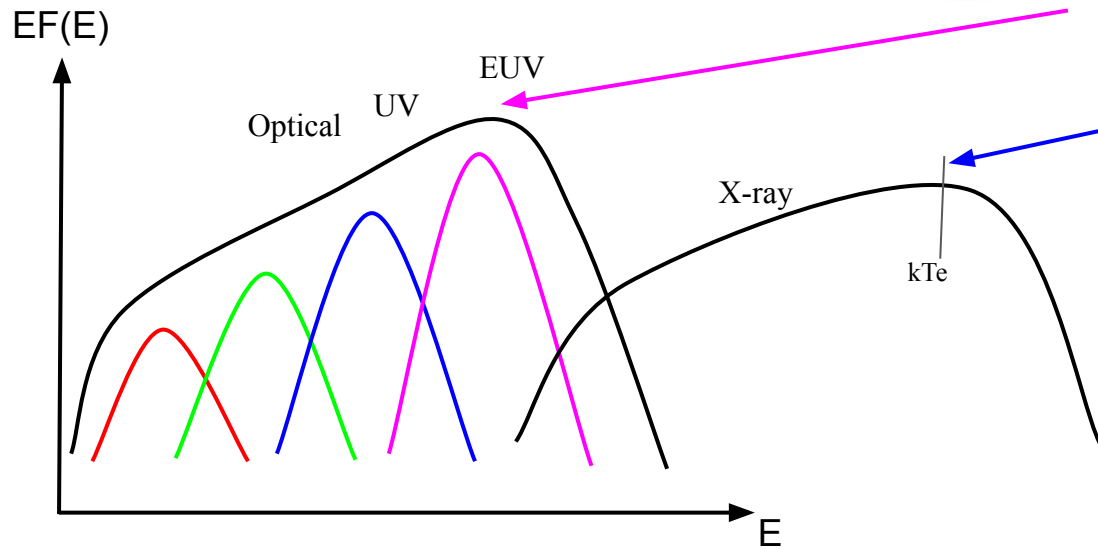
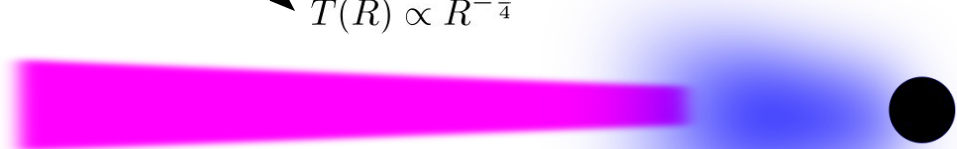


Generic AGN picture, 'unified model': **Antonucci 1993**

# Building an AGN SED

Accretion disc gives multi-colour  
black-body emission in optical/UV  
Shakura & Sunyaev (1973)

$$T(R) \propto R^{-\frac{3}{4}}$$



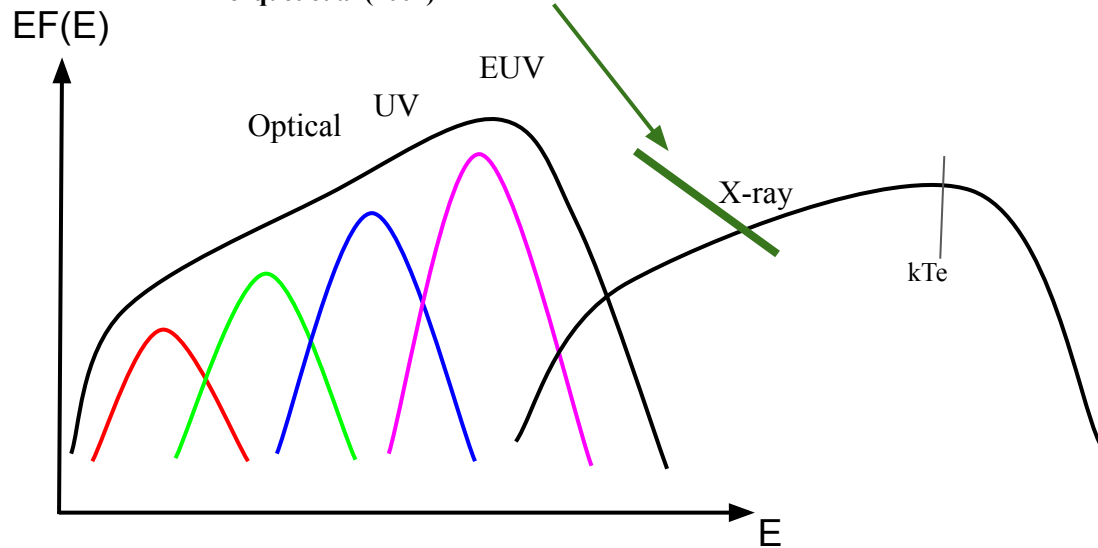
Optically thin, geometrically  
thick, X-ray hot (~100 keV)  
plasma generates Comptonised  
spectrum in the X-ray

e.g Elvis et al. (1994); Fabian et al. (2015);  
Porquet et al. (2018); Kubota & Done (2018)

# Building an AGN SED

Observations show an up-turn in the soft X-rays, leading back towards the UV

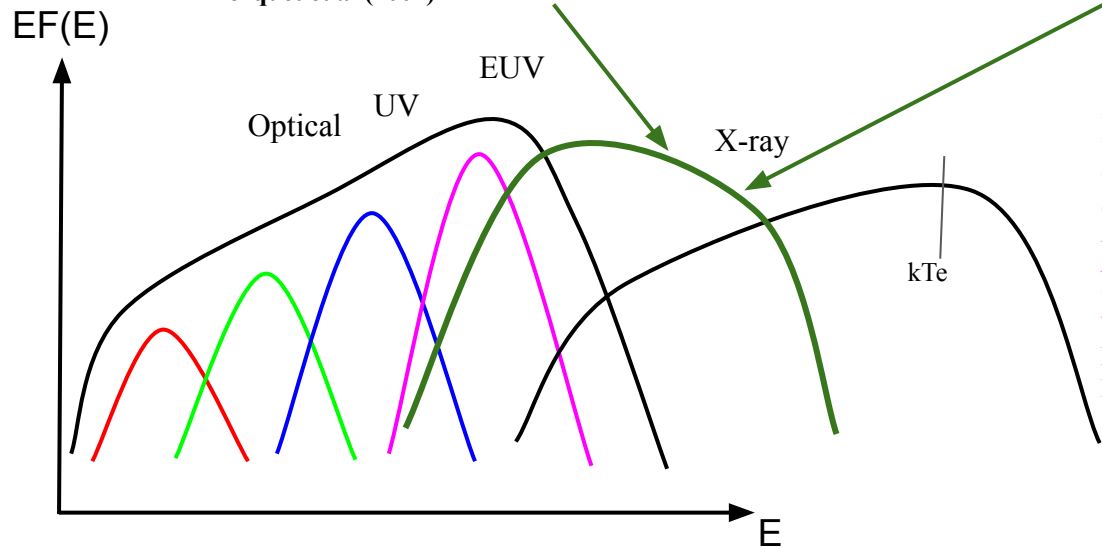
Laor et al (1997), Gierlinski & Done (2004), Porquet et al (2004)



# Building an AGN SED

Observations show an up-turn in the soft X-rays, leading back towards the UV/EUV

Laor et al (1997); Gierlinski & Done (2004); Porquet et al (2004)



If the disc fails to thermalise, forming instead a disc-like structure, then emission should come out as Comptonised black-body rather than black-body

Naturally leads to a spectral shape that links the soft X-ray excess to the UV turn-over

Mehdipour et al. (2011, 2015); Done et al. (2012); Petrucci et al. (2018); Kubota & Done (2018)

- **Mass** and **Mass Accretion rate** sets bolometric luminosity
- $r_h$ ,  $r_w$  set the power in each component

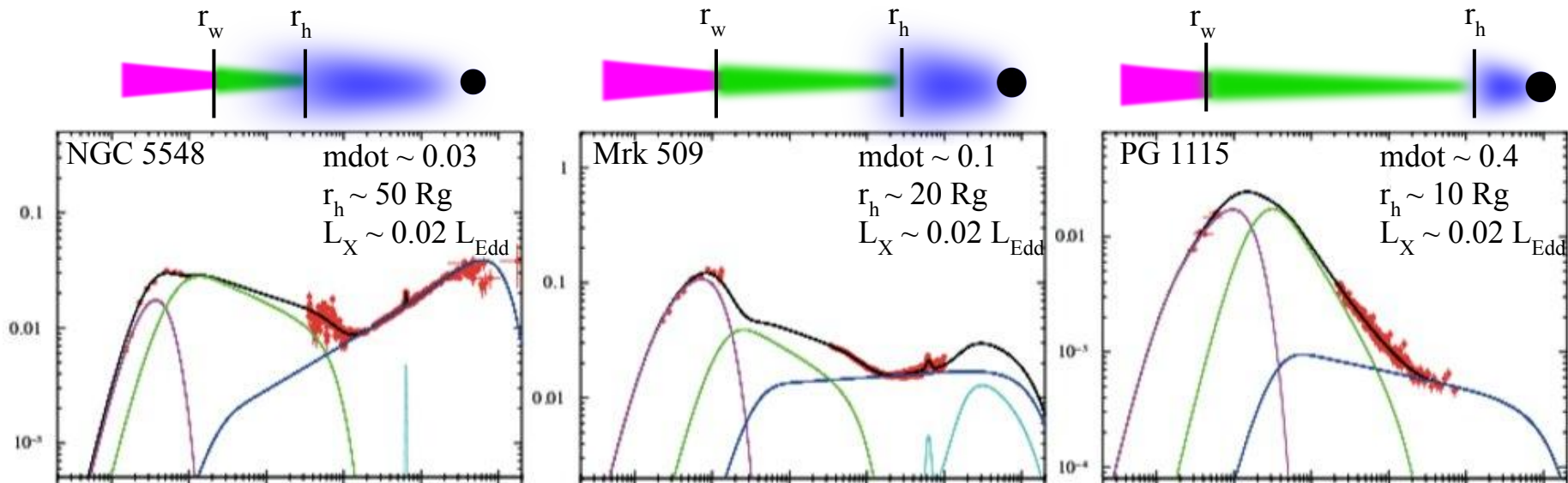


Figure taken from: **Kubota & Done 2018**  
 All sources have Mass  $\sim 10^8 M_{\text{sol}}$

- The energy balance sets the size scale of each emitting component
- **The X-ray luminosity always appears at  $L_X \sim 0.02 L_{\text{Edd}}$**

# AGN SEDs

Fundamentally depends on **Mass** and **Eddington Ratio**

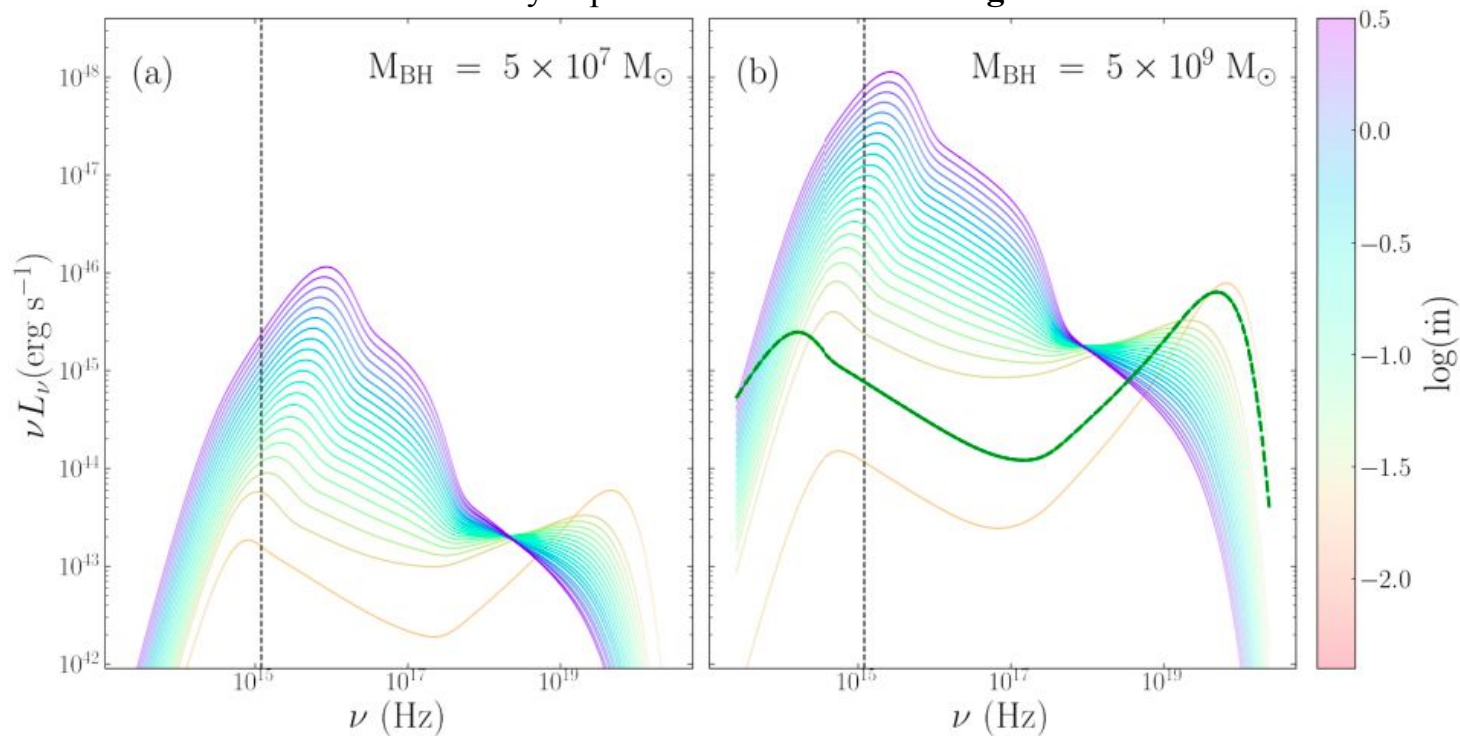


Figure from: Mitchell..SH..et al. (2023)

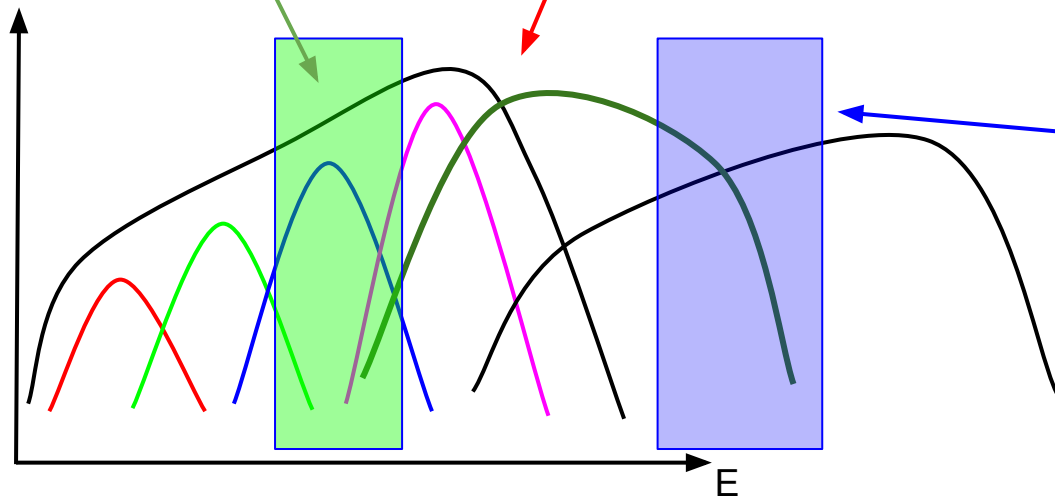
# Observing AGN

Optical/UV generally (not always) on Rayleigh-Jeans tail. Power-law shape

EUV generally contains most of the power - however unobservable due to galactic absorption!



$EF(E)$



Strong X-ray emission a sign of AGN activity



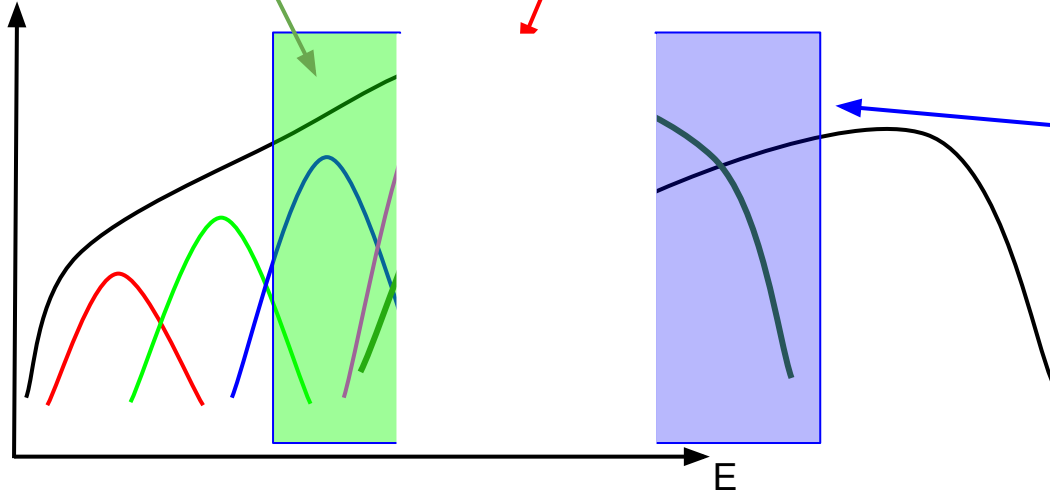
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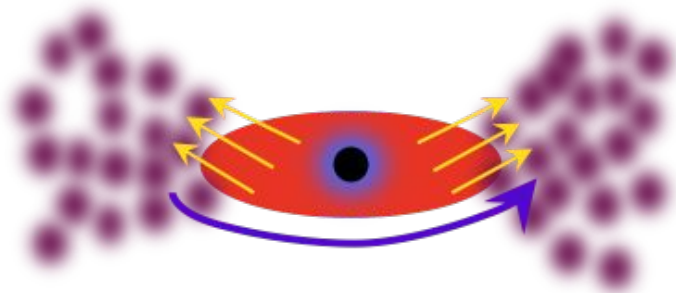


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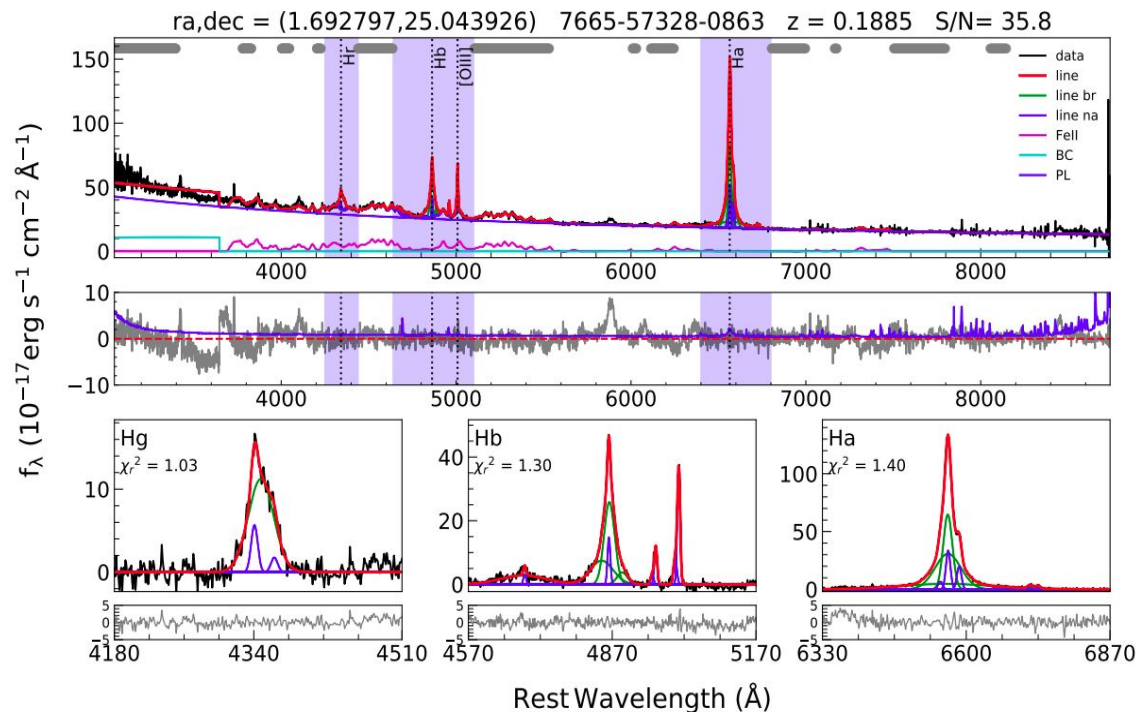
Strong X-ray emission a sign of AGN activity

# Identifying AGN through Broad Lines



- EUV emission from disc illuminates 'cloud' BLR structure
- Induces emission lines
- Orbital motion broadens the lines
  - $> \sim 1000 \text{ km/s}$

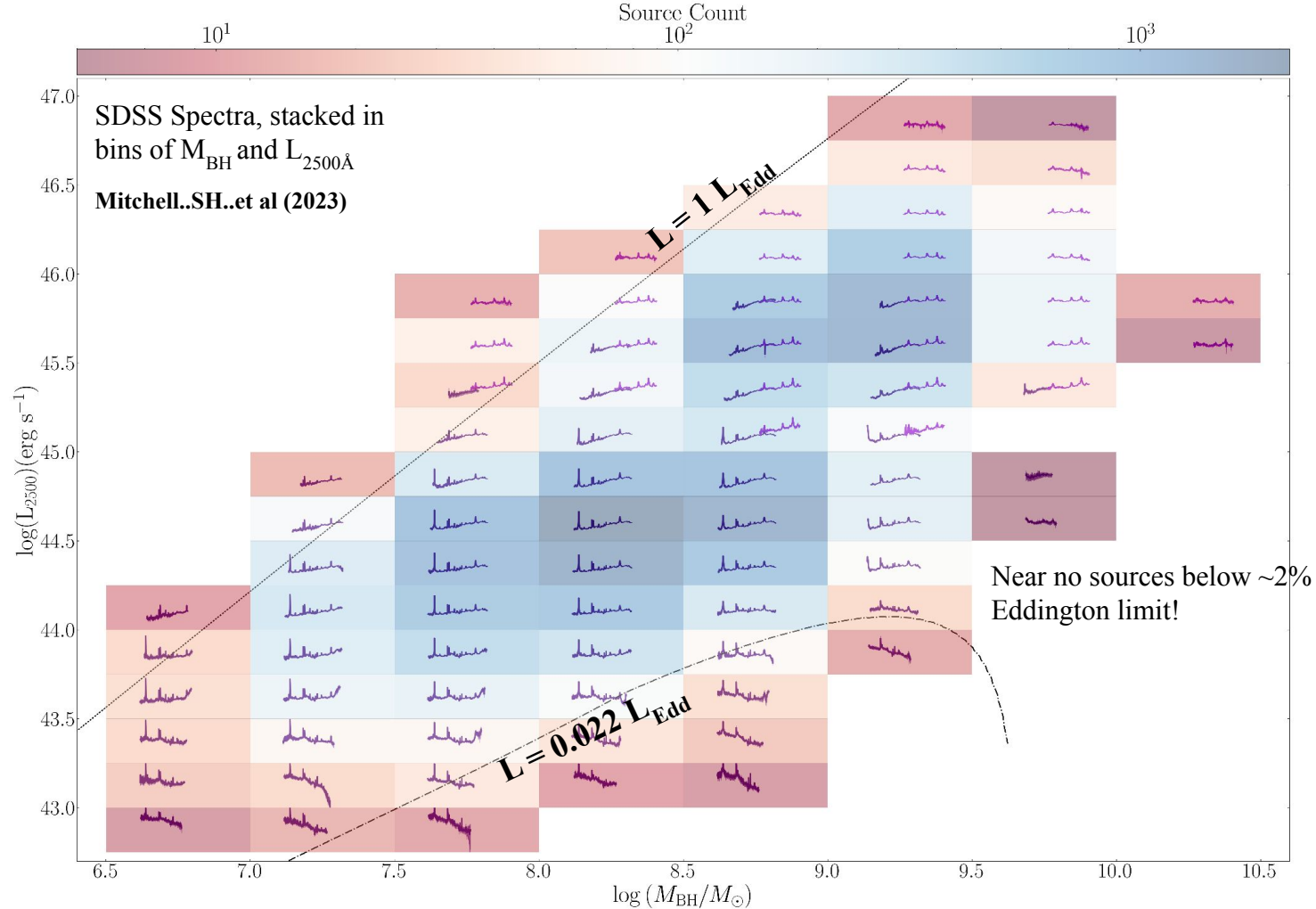
Figure taken from: **Rakshit et al. 2020**

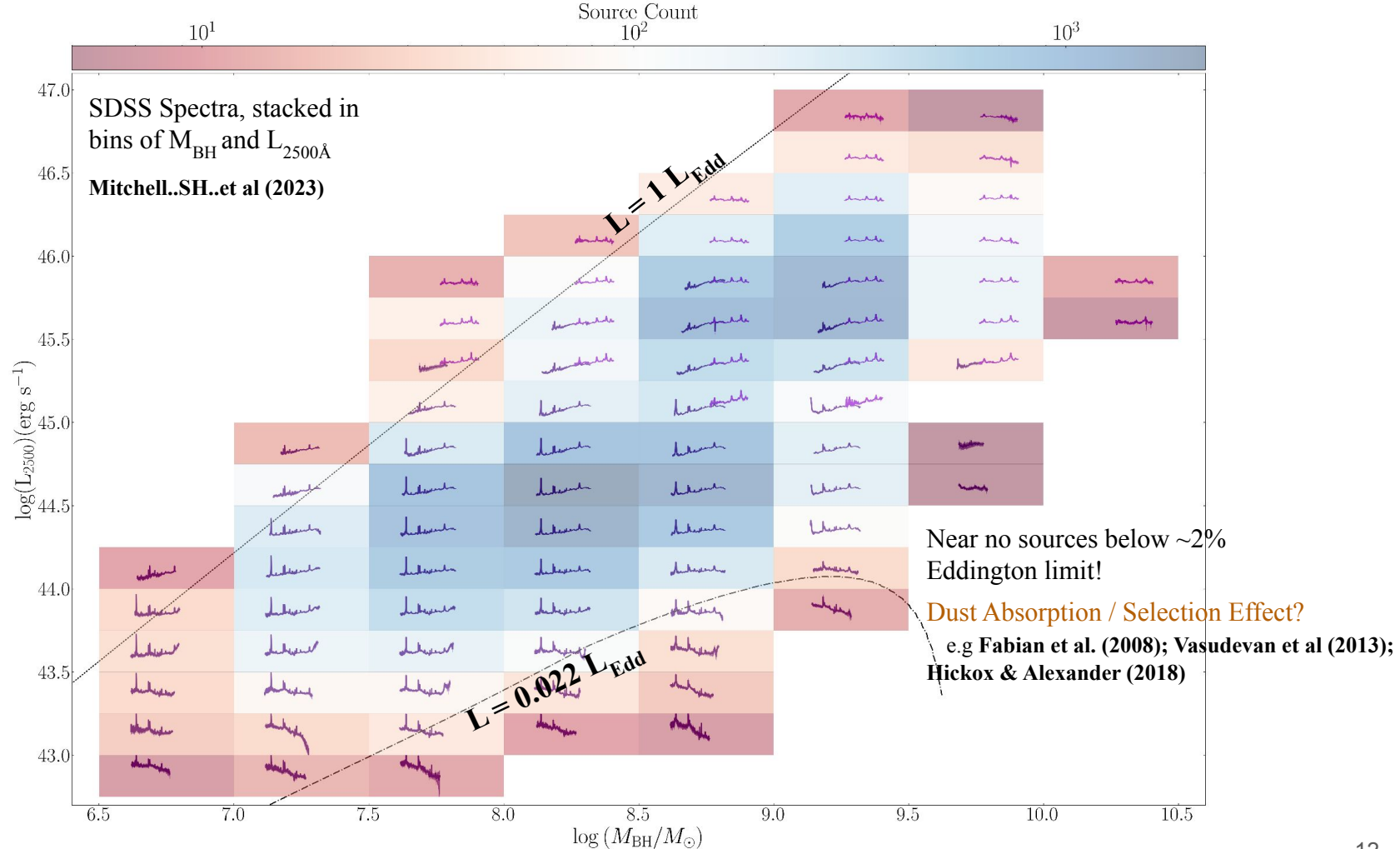


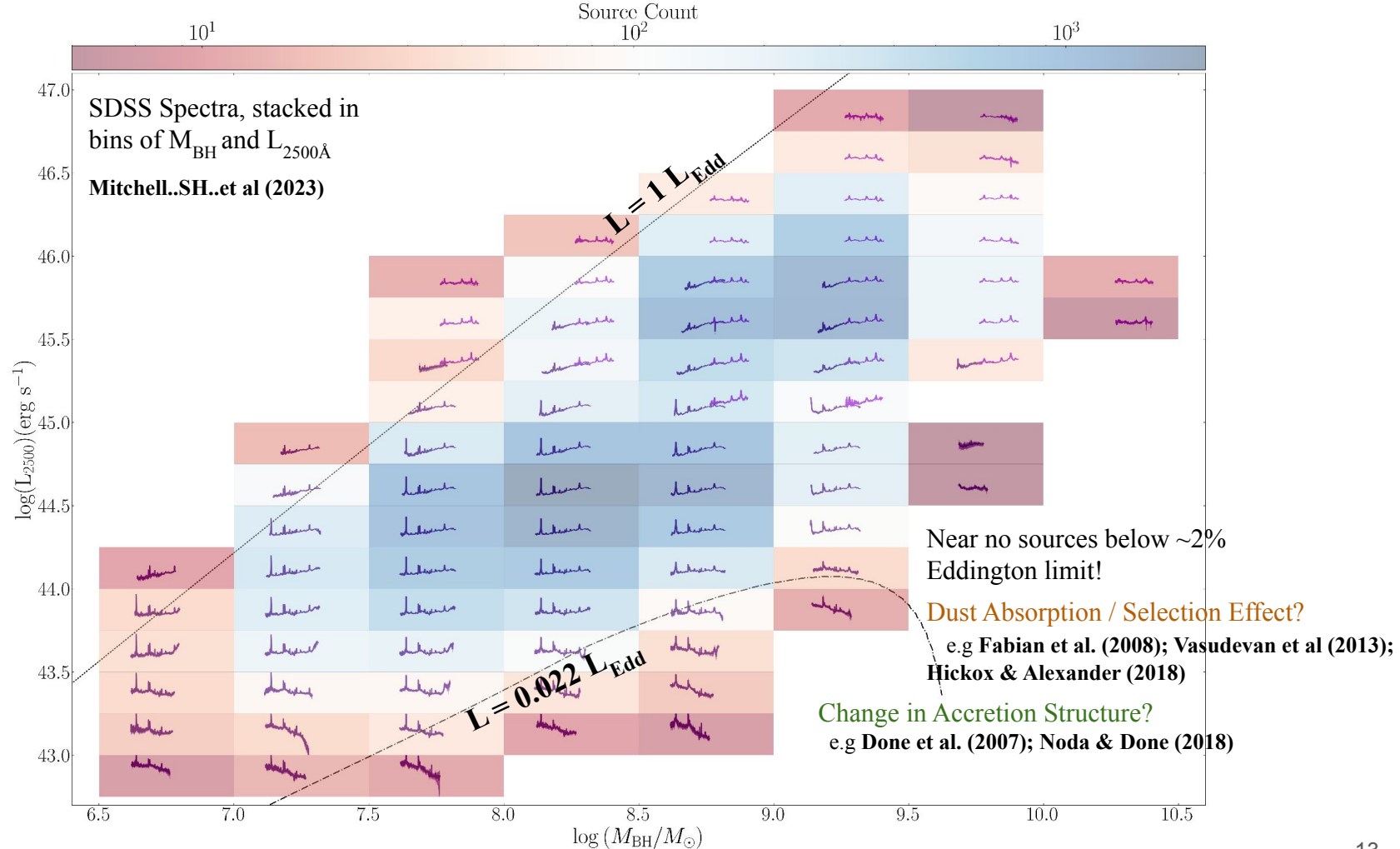
Typical SDSS Quasar Spectrum

Characterised by:

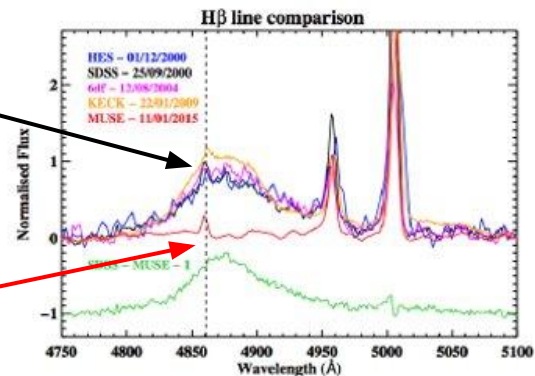
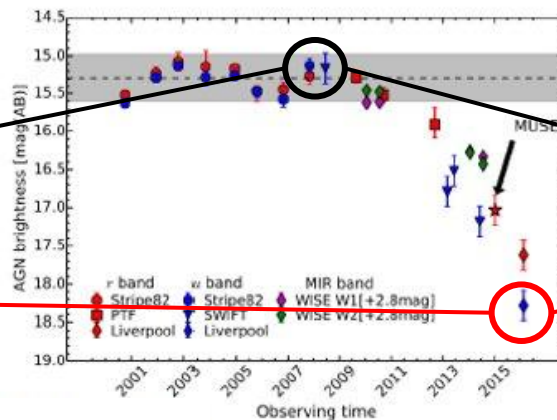
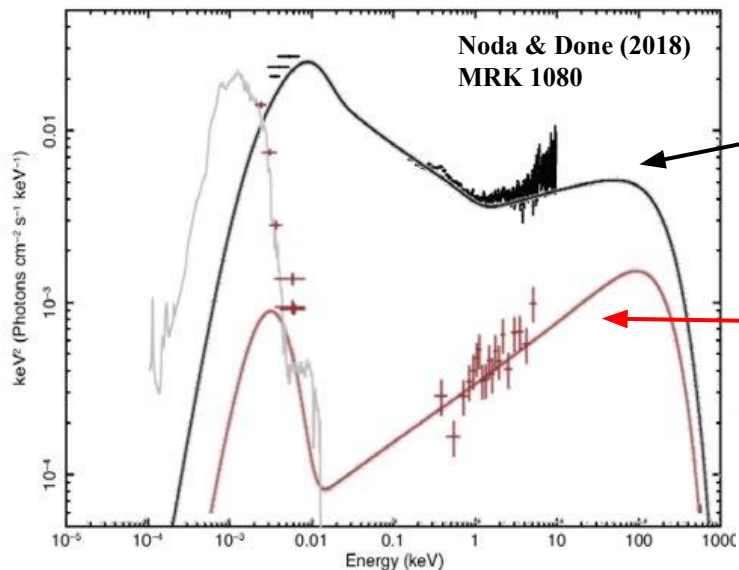
- Broad emission lines
- Power-law 'like' continuum







# Change in accretion structure motivated by Changing-State

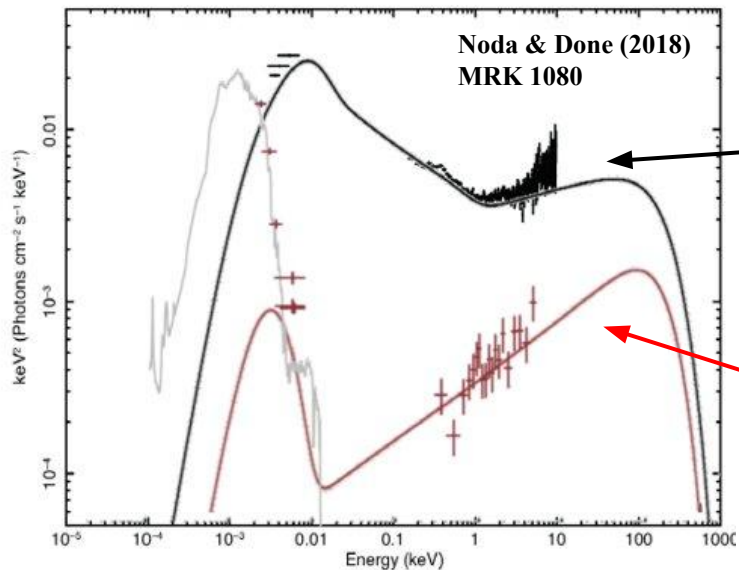


MRK 1018 - McElroy et al. (2016)

Broad line disappears due to a loss of the ionizing EUV radiation!

Drop in Optical flux corresponds to dramatic change in the SED, and corresponding loss of broad emission line in Hbeta

# Change in accretion structure motivated by Changing-State



$L/L_{\text{Edd}} \sim 0.07$



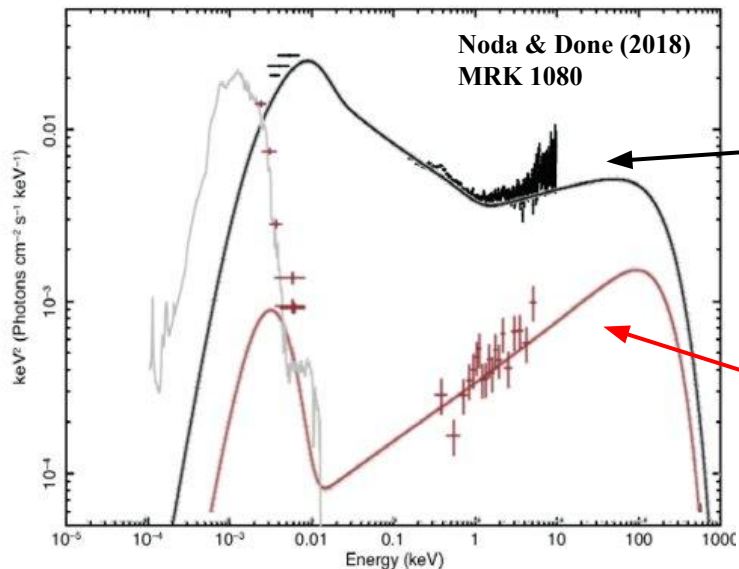
$L/L_{\text{Edd}} \sim 0.005$



State transition remarkably similar to those seen in galactic BHBs!

Can be explained with a dramatic change in the accretion structure, caused by a change in mass-accretion rate

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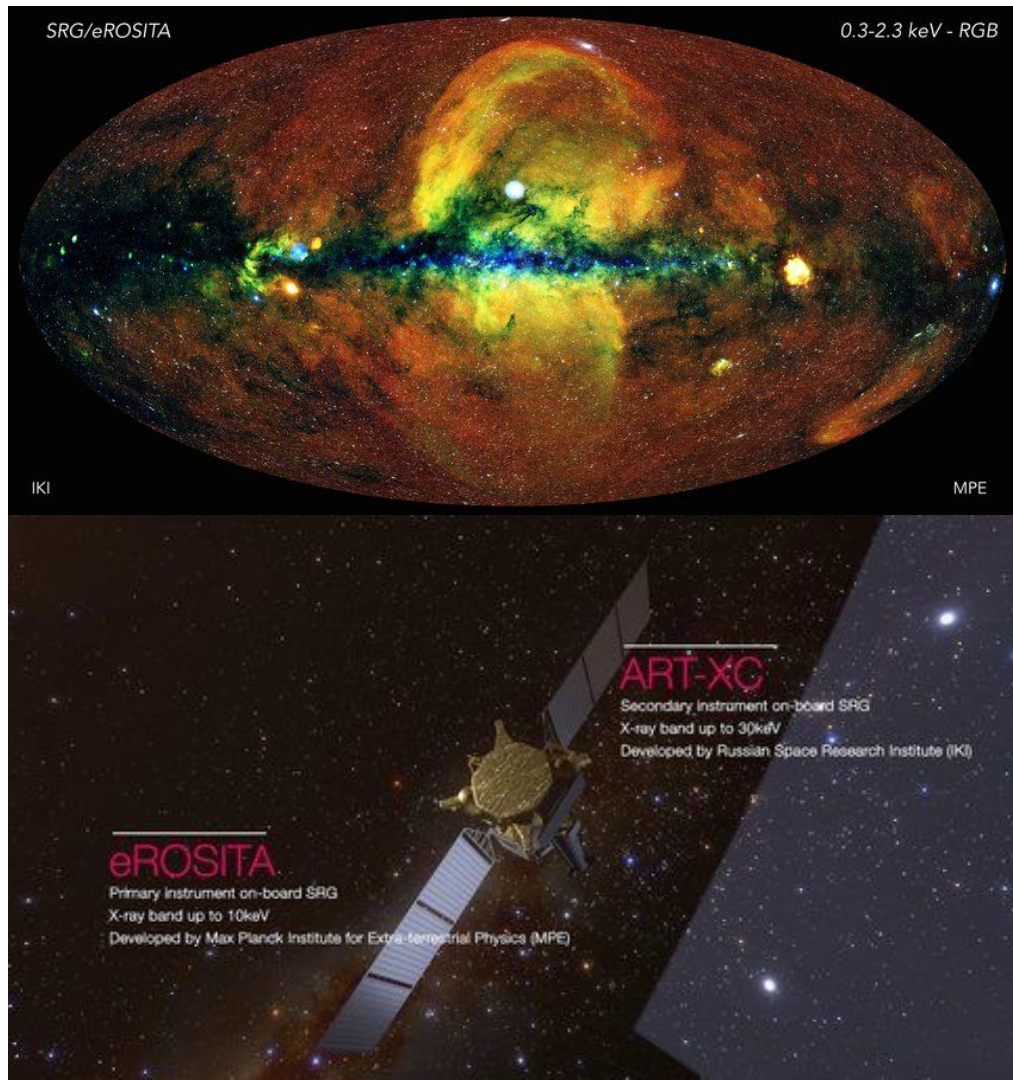
**Is this simply weird behaviour for a handful of rare objects, or is it present in the wider AGN population?**



# Sample Selection

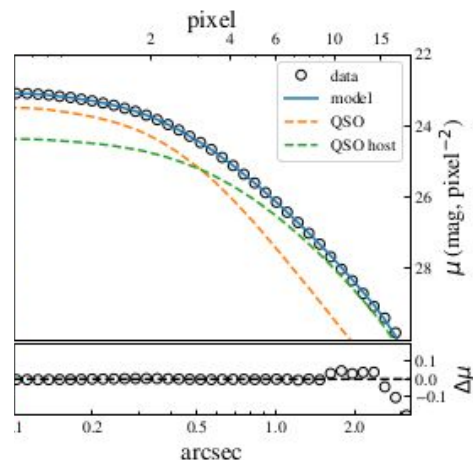
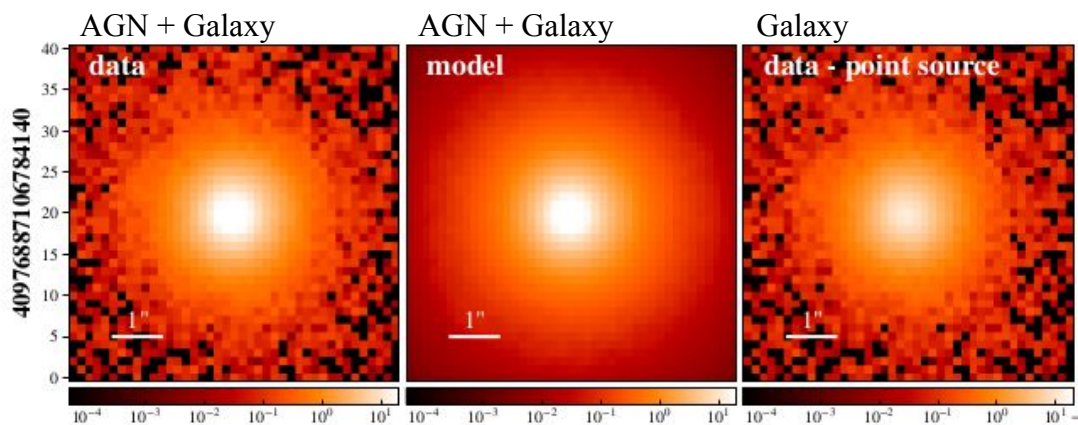
- X-Ray Selection Allows us to pick out AGN regardless of the presence of broad emission lines
- eROSITA all sky survey perfect for this!
- eFEDS field (100sq deg) contains 22 079 AGN sources
  - **Liu et al. (2022)**

Image credit:  
**Max Planck Institute for  
Extraterrestrial Physics**



# Sample Selection - Optical Counterpart

- eFEDS has HSC Optical follow up
  - Sub-arcsecond imaging - 8m class telescope
- HSC allows for confident AGN-Host decomposition
  - **Li et al. (2021a, 2023); Ding et al. (2021, 2023)**



# Sample Selection

- **Li et al. (2023)** performed optical decomposition of  $\sim 3800$  HSC-eROSITA AGN in the eFEDS field
  - Redshift: 0.2-0.8
- This forms the basis of our study!
- We select X-ray unobscured objects, to ensure we are viewing the central accretion flow
- The sample is then subdivided into **BH Mass** (or Mstellar as a proxy) and **3500 Å Luminosity** bins

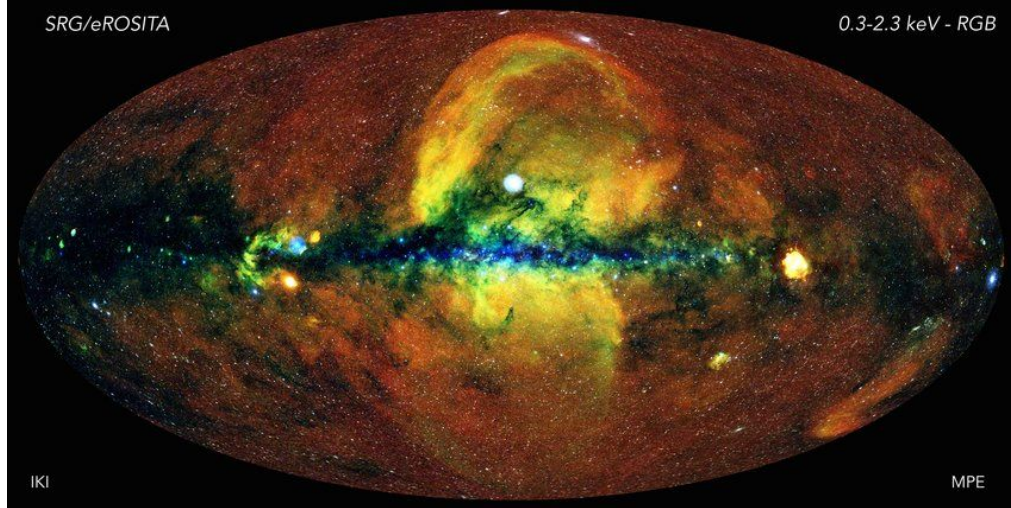
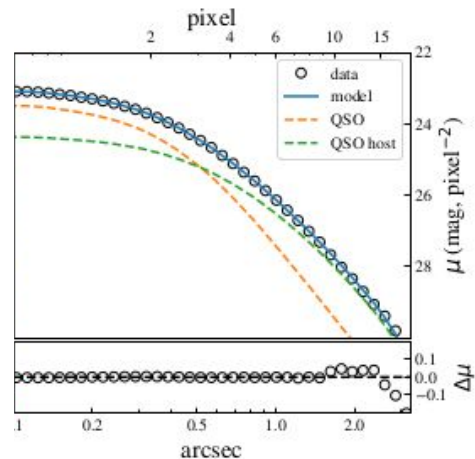
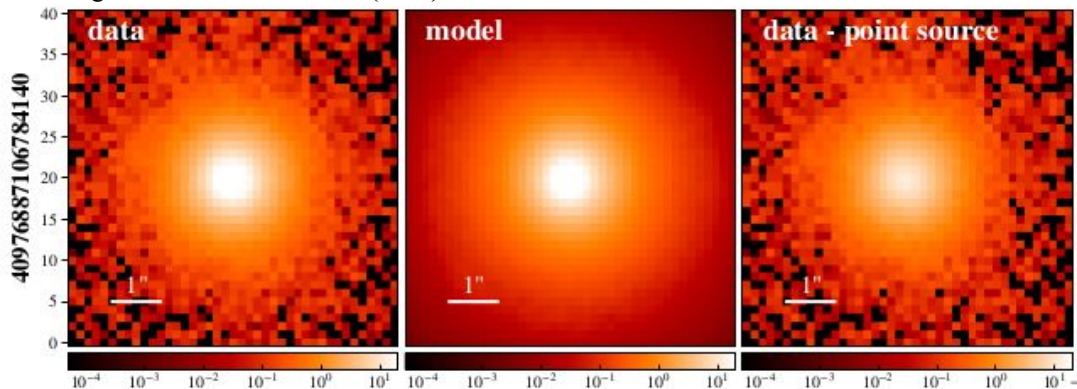
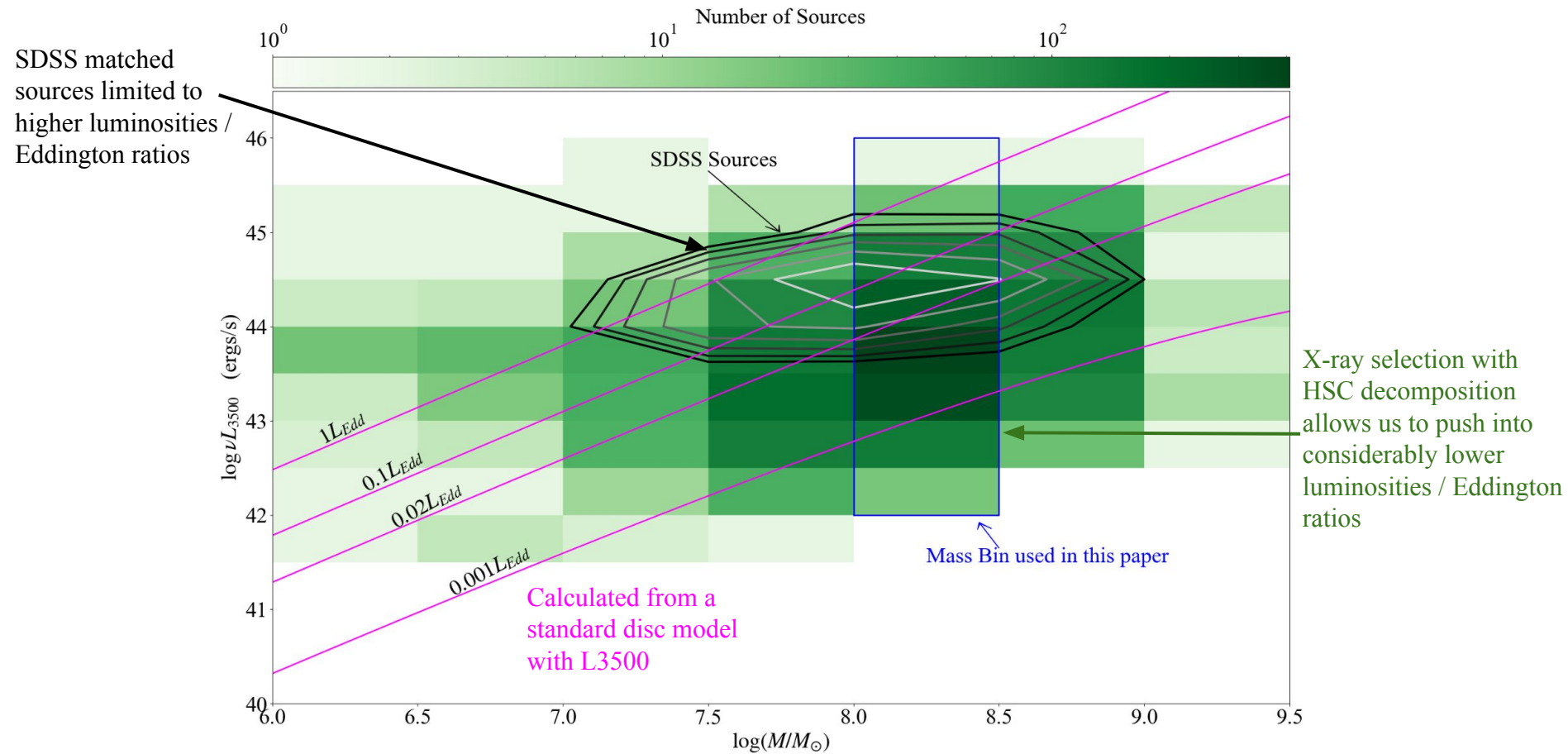
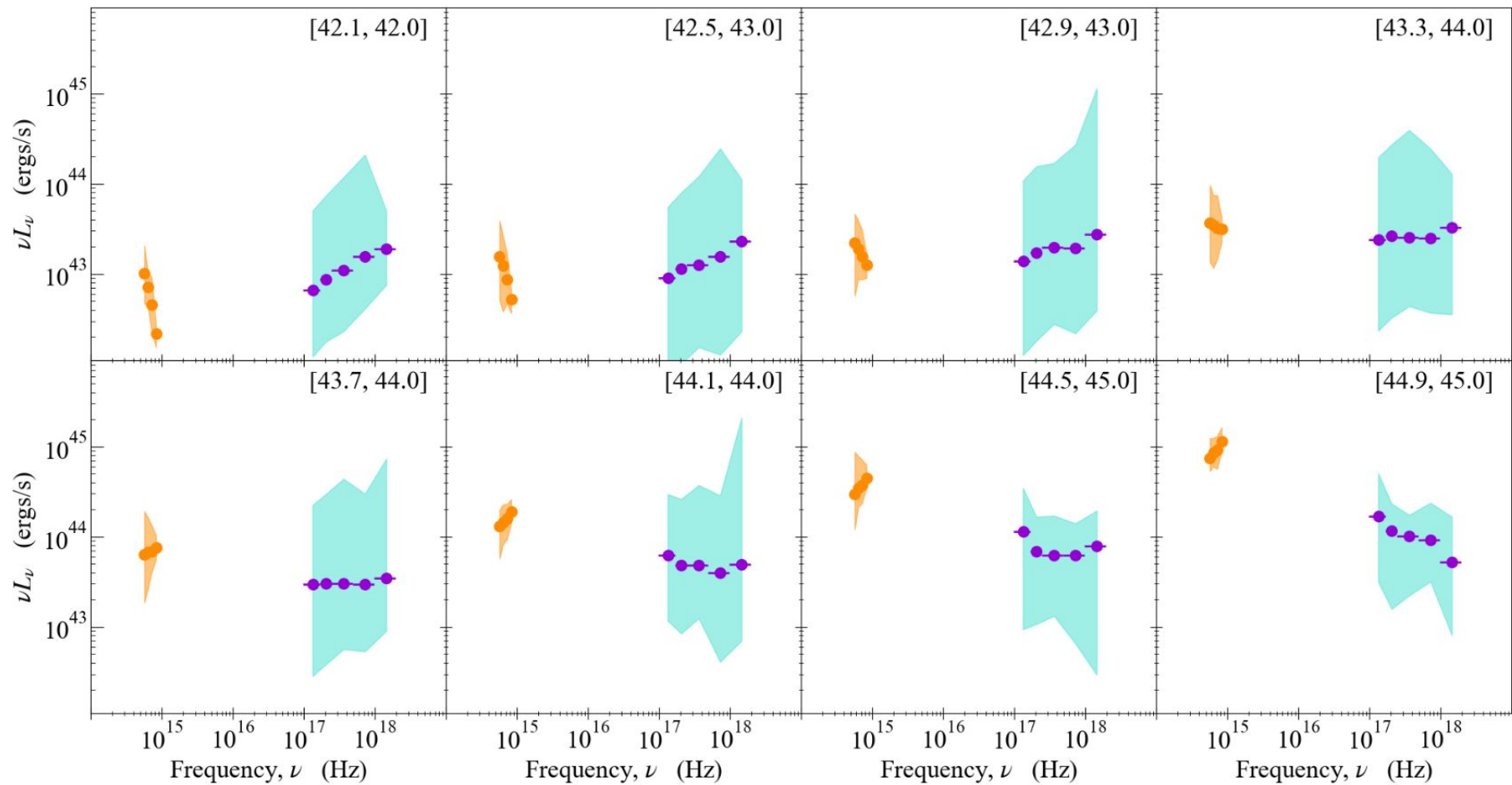
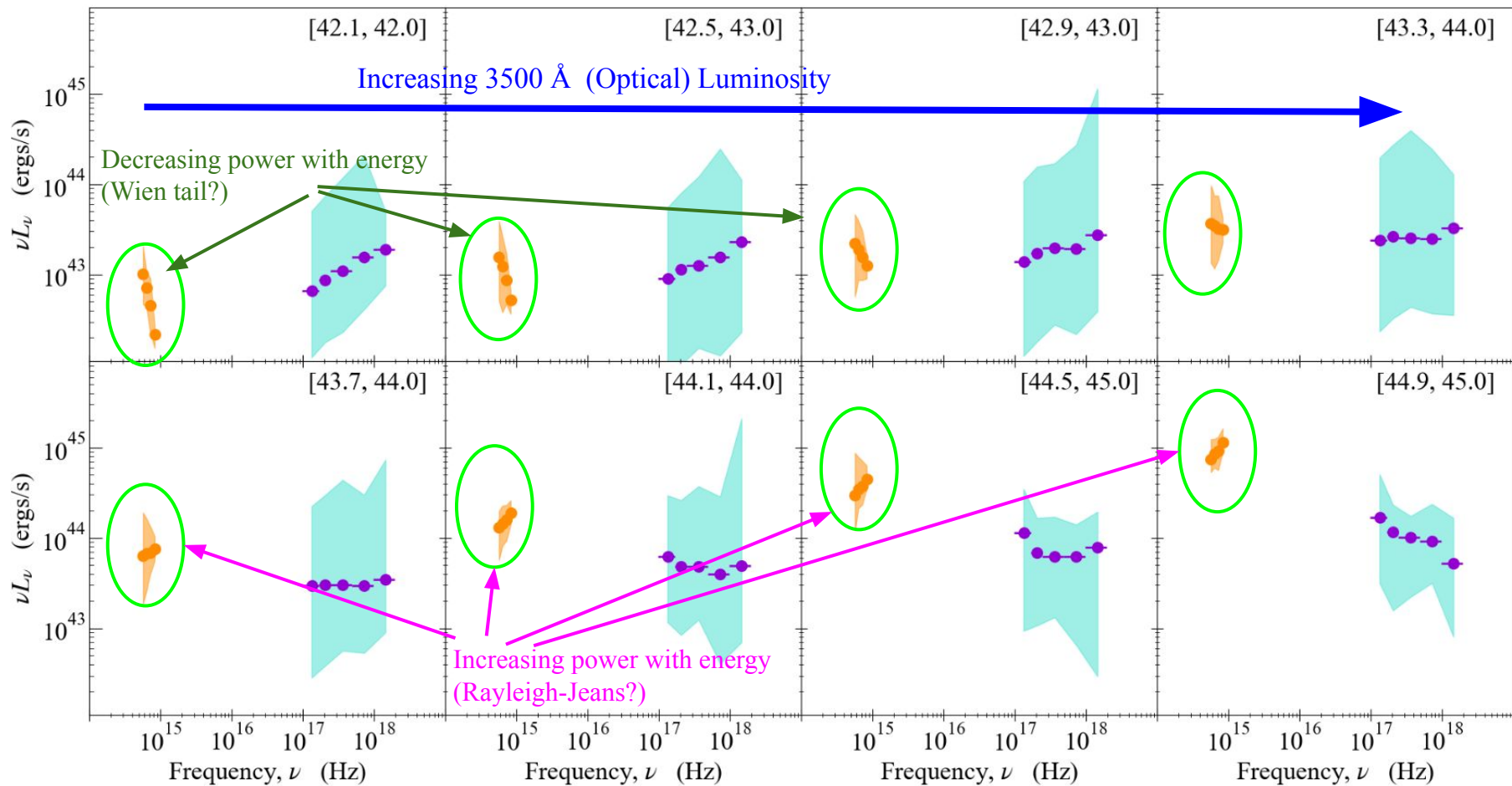


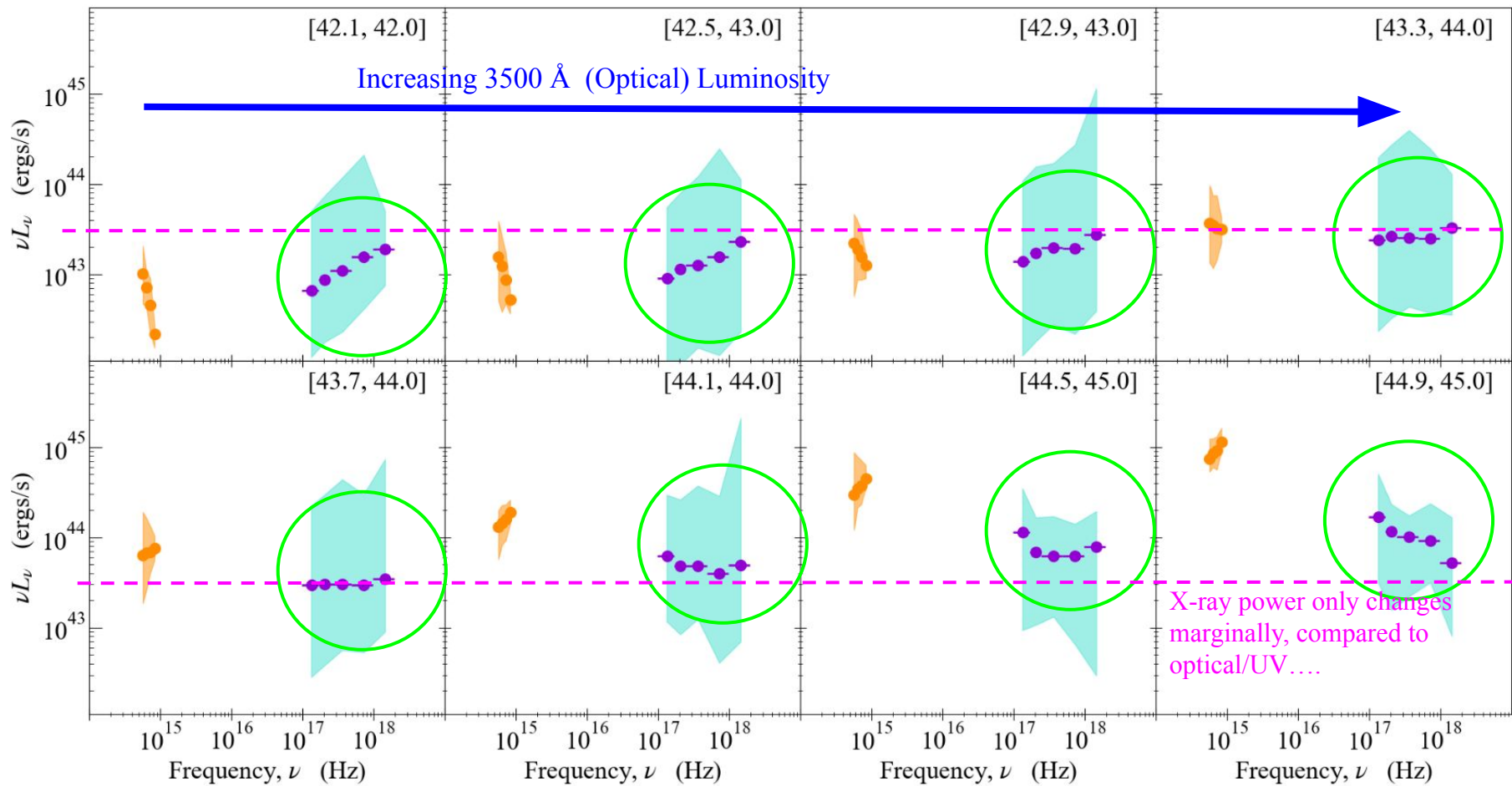
Figure taken from: **Li et al. (2023)**

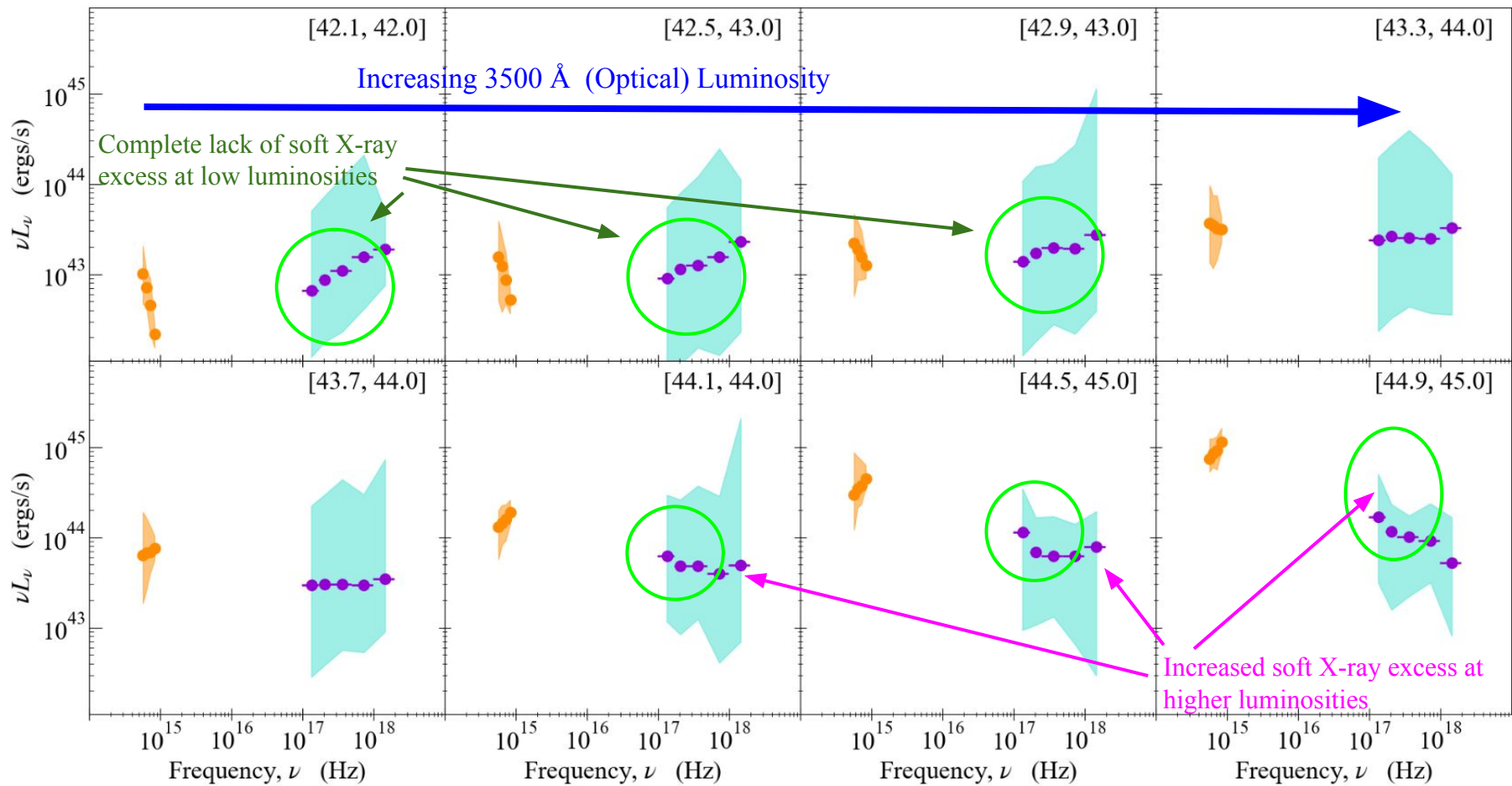




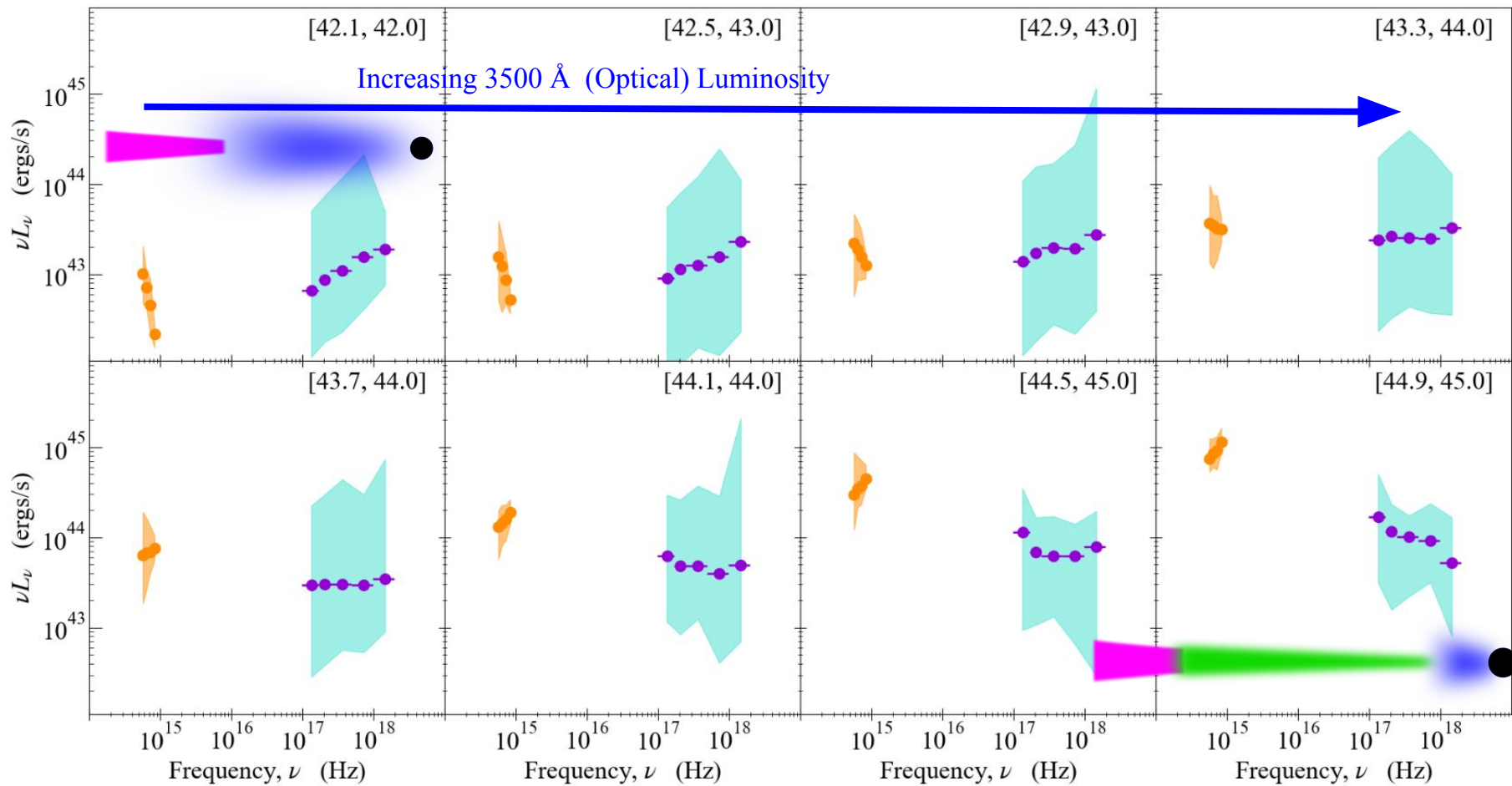


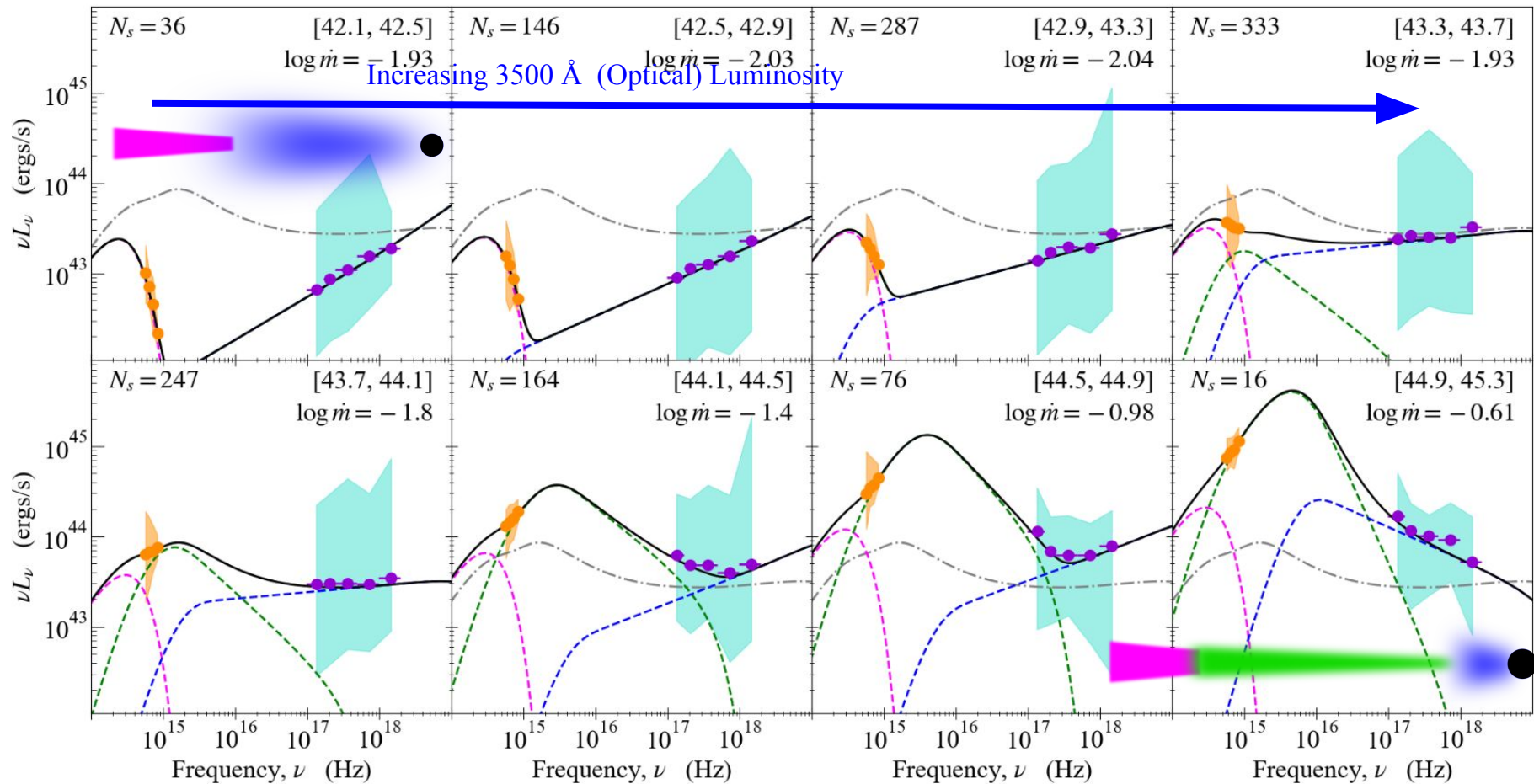


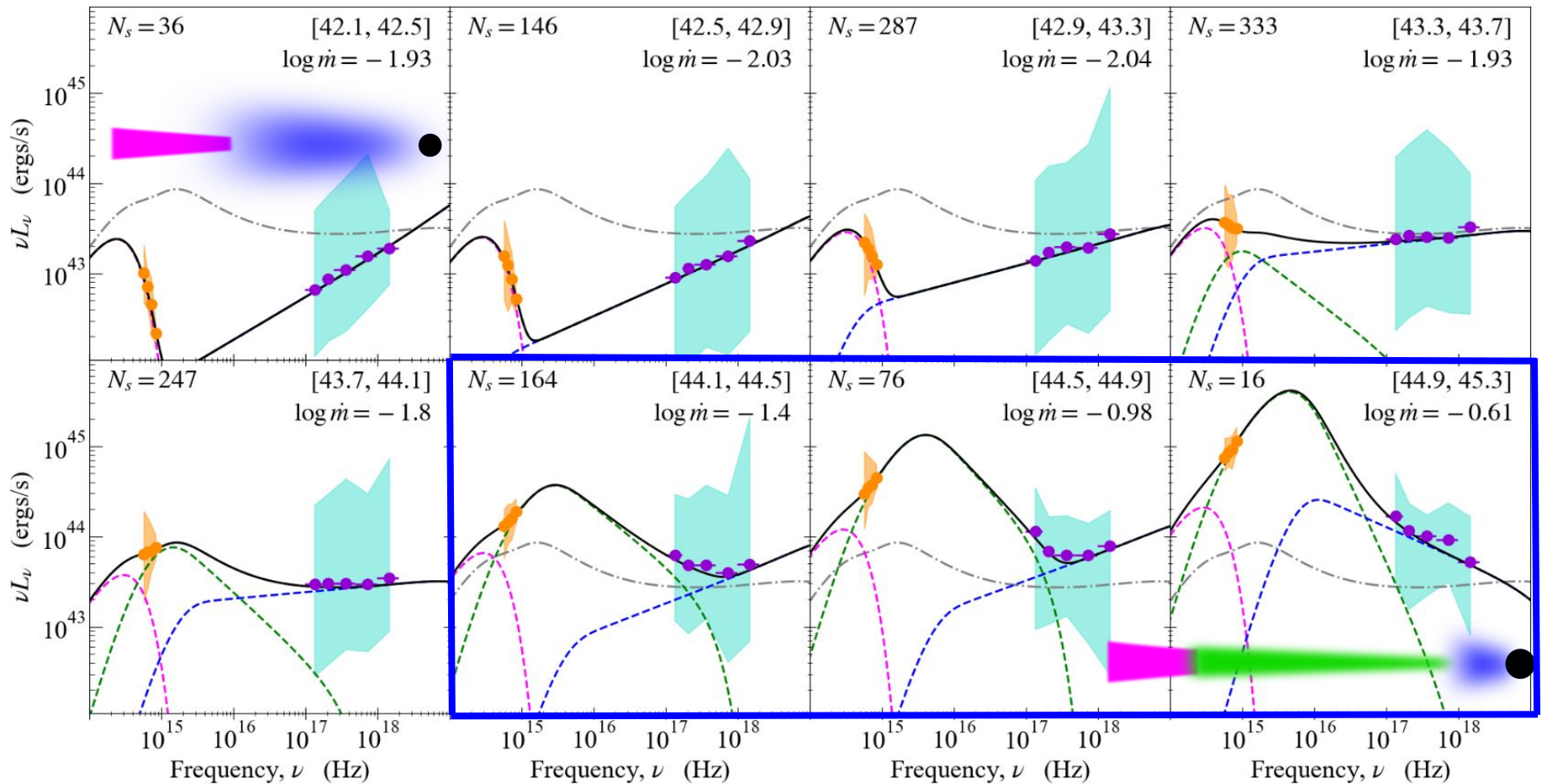


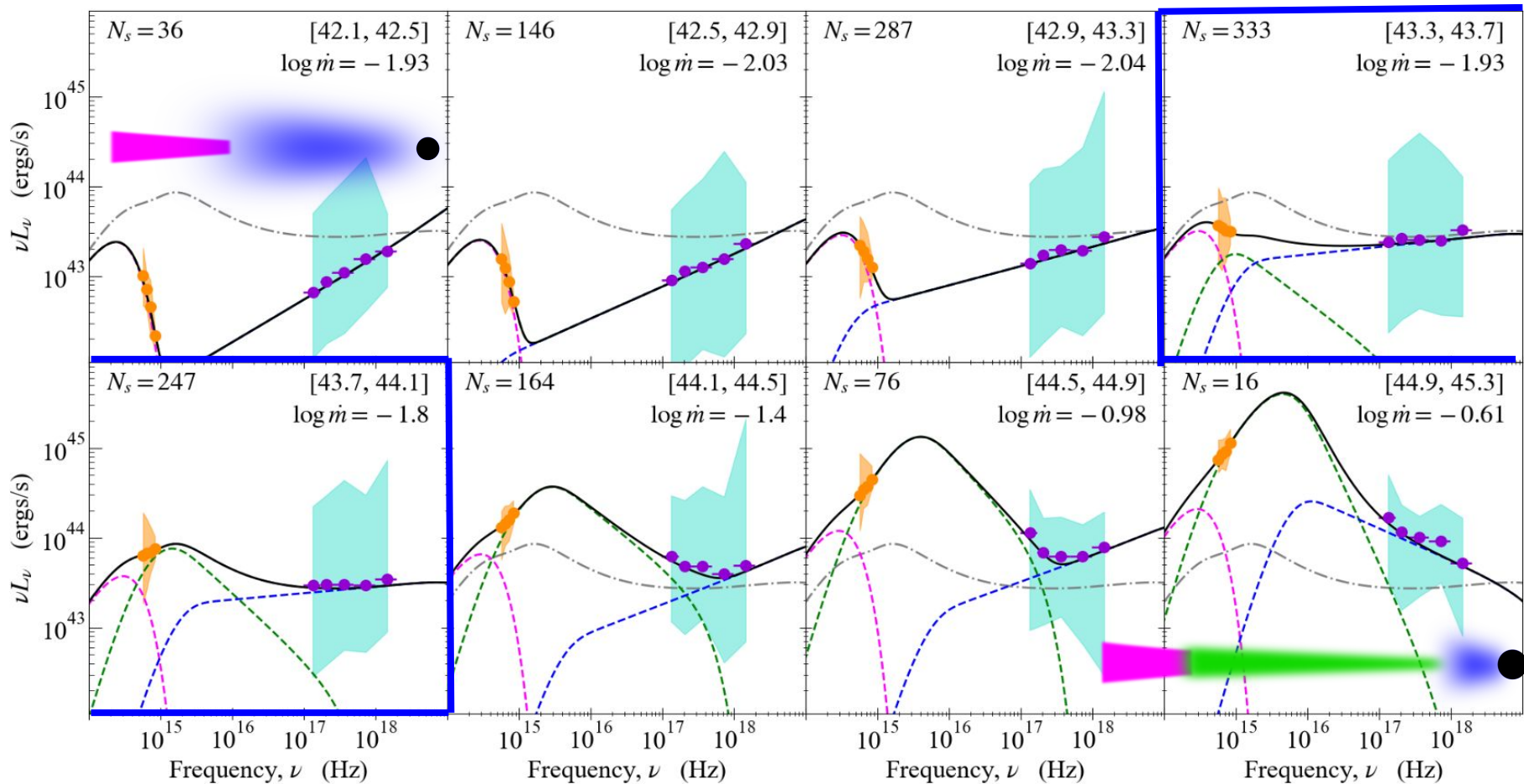


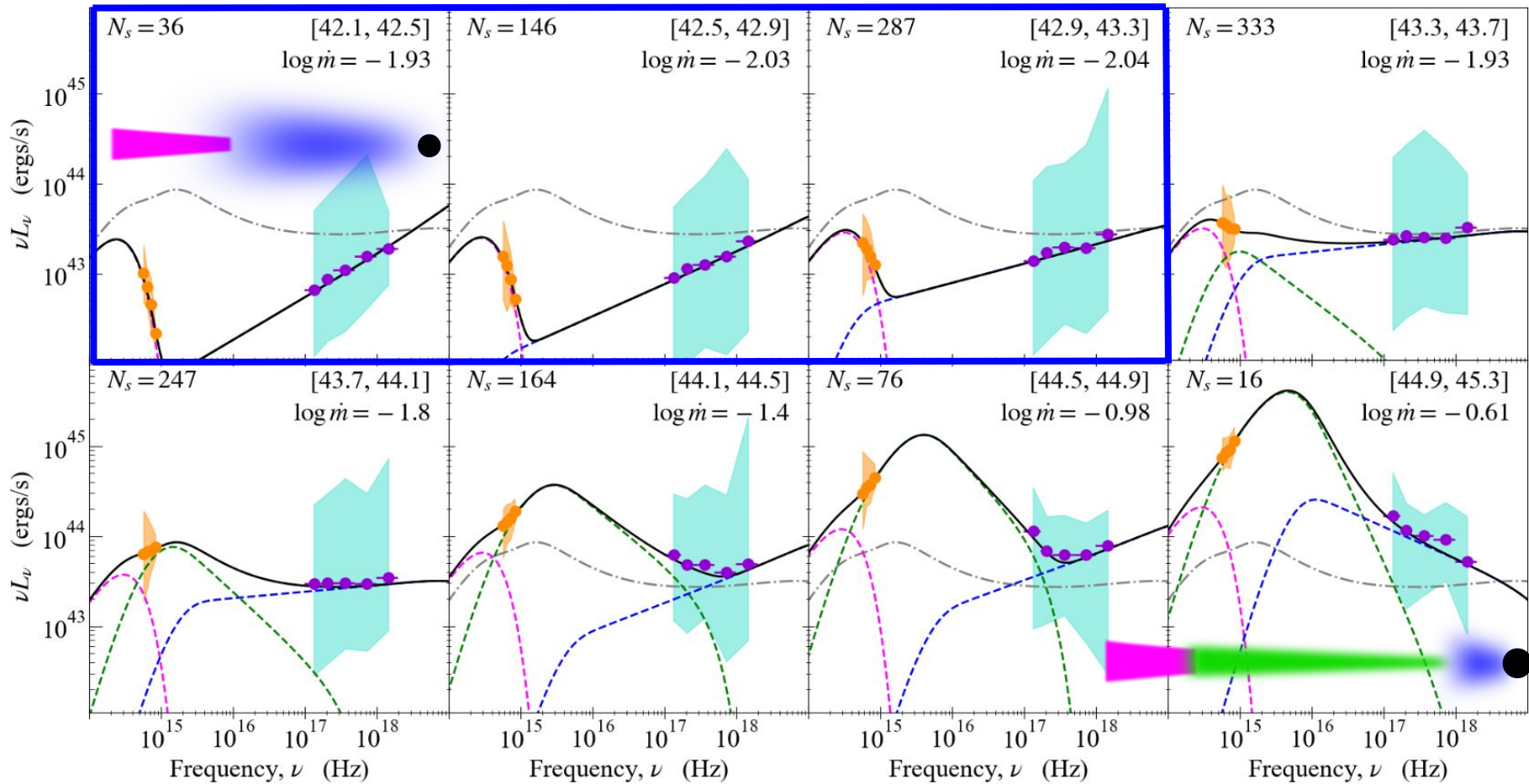


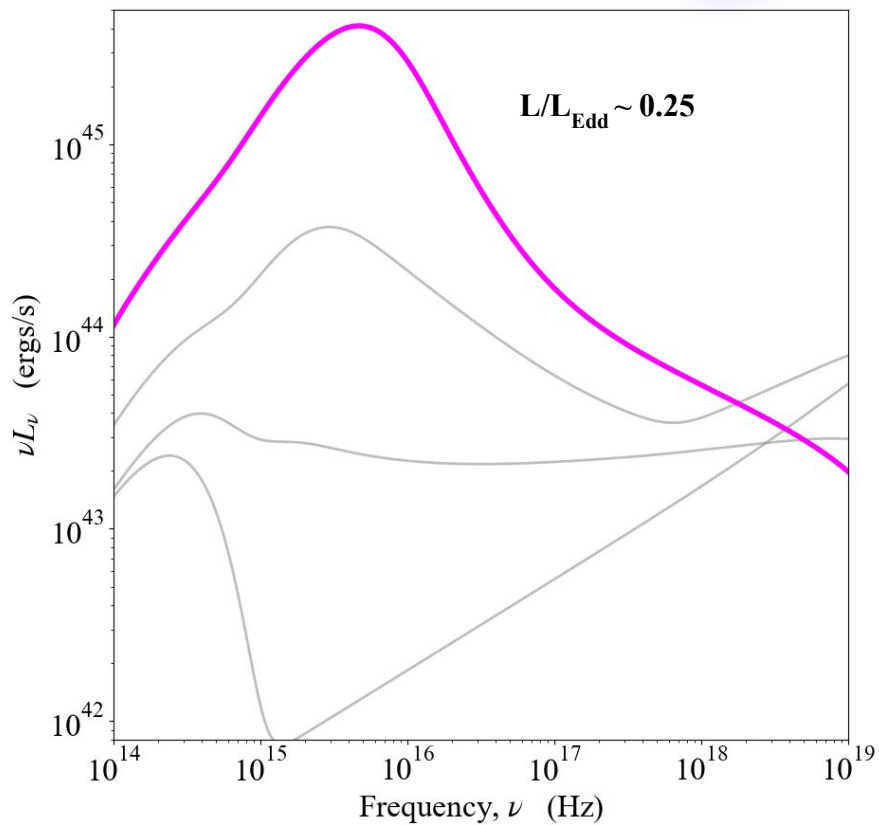




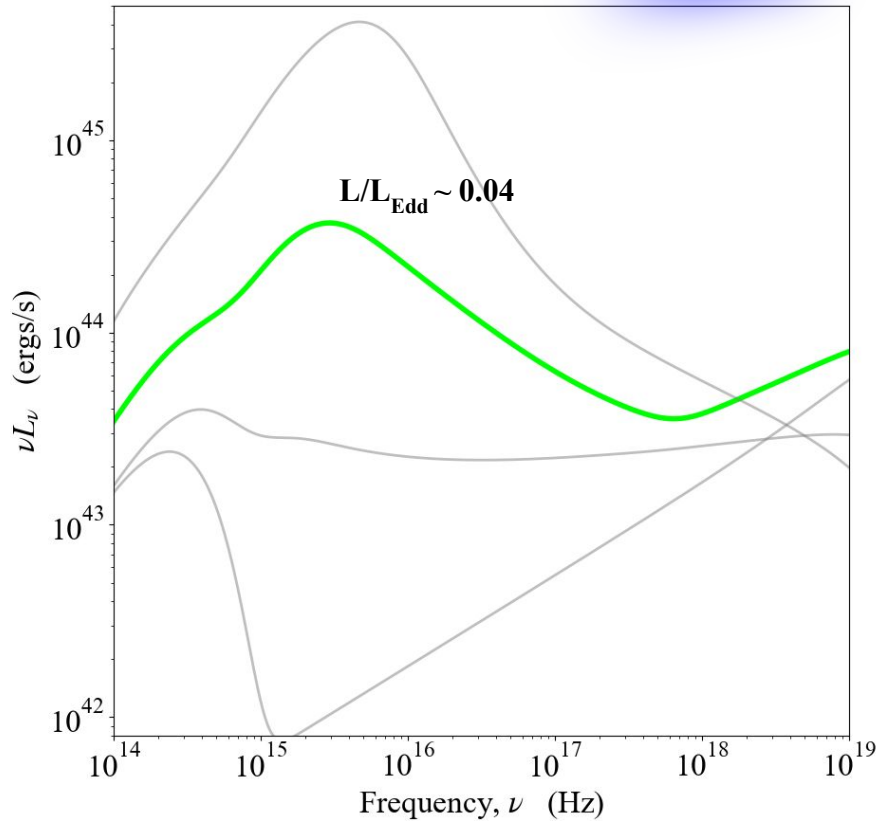






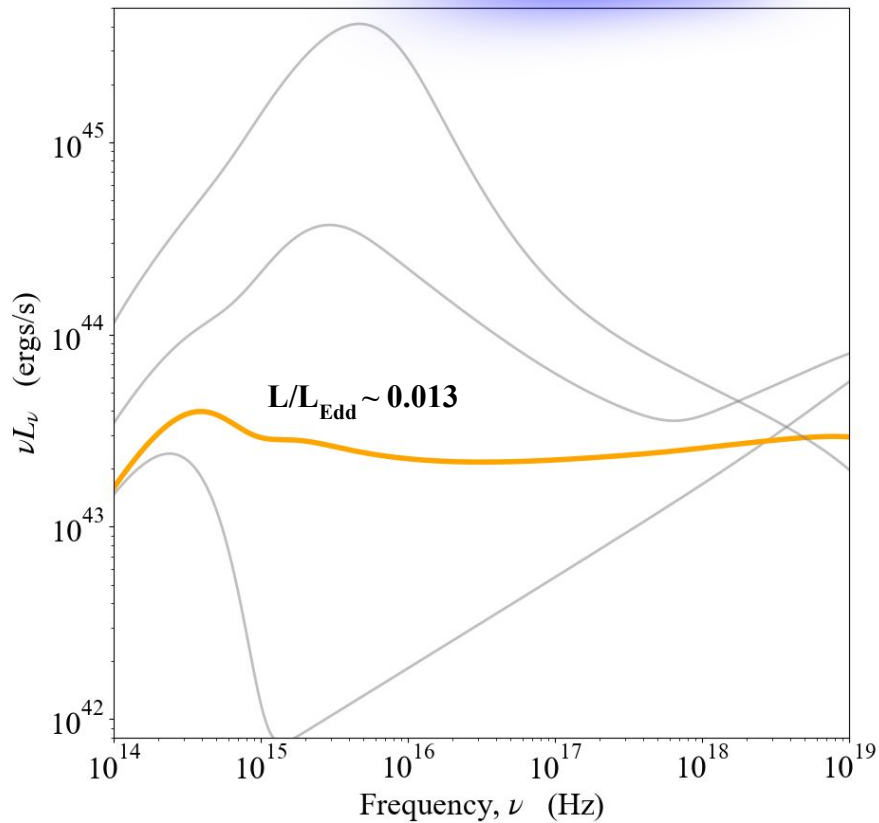


At high Eddington fractions the flow is dominated by a disc-like structure



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This gets weaker as the Eddington fraction reduces

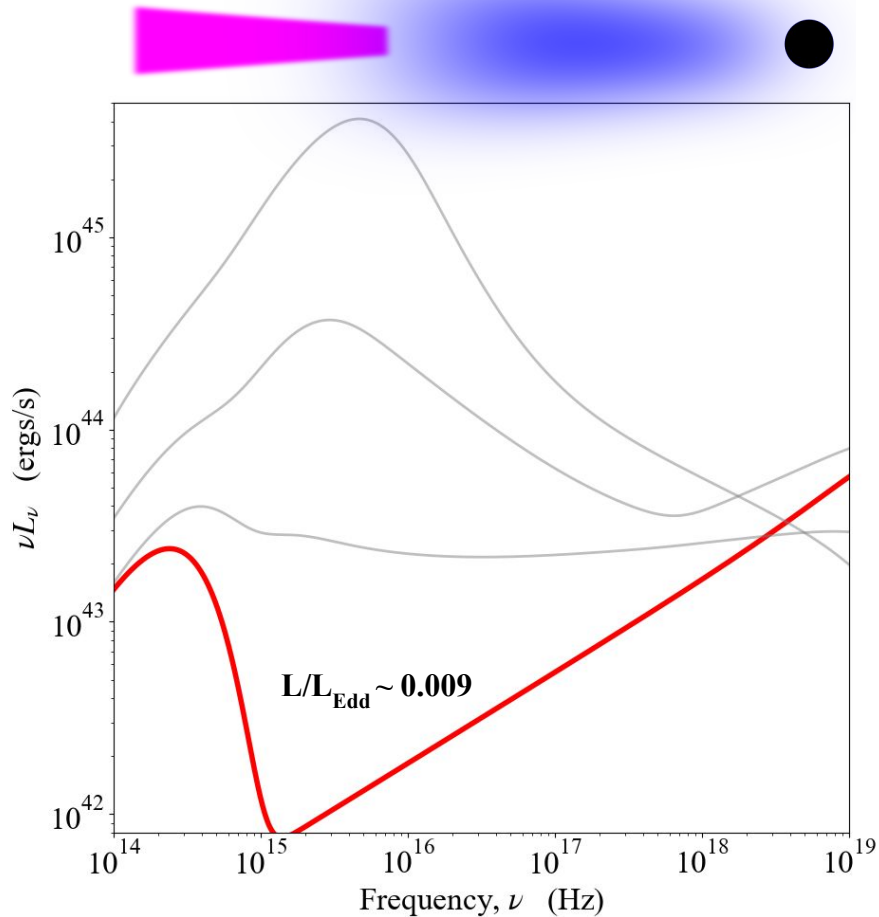


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Around the changing-look transition we have comparable power emitted by the disc and corona





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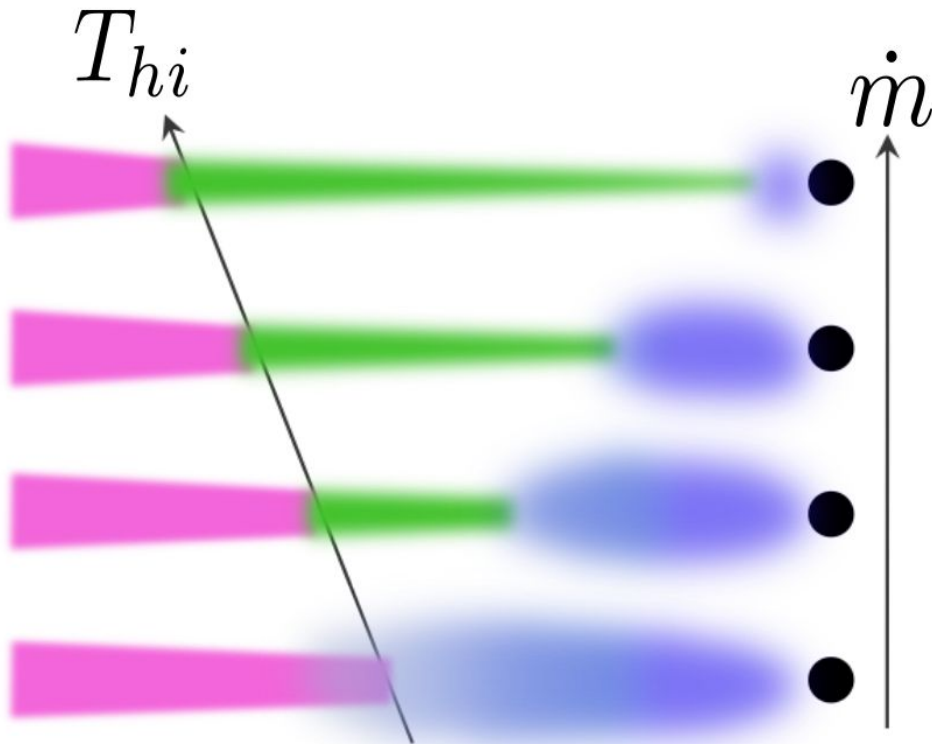
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Around the changing-look transition we have comparable power emitted by the disc and corona

Past the changing-look/state transition, the inner disc-like structure completely collapses. Leaving a flow dominated by an inner X-ray hot plasma (and the remains of an outer disc)

# Summary / Conclusions

- There is a change in accretion structure, as the flow transitions from a disc dominated state, to an X-ray dominated one
- At low Eddington ratios the accretion disc ‘collapses’, giving way to an X-ray hot plasma
- This impacts how we identify AGN and understand BH growth through cosmic time
- **Hagen, Done, Silverman et al. (submitted)**
  - arXiv: 2406.06674



See Also:

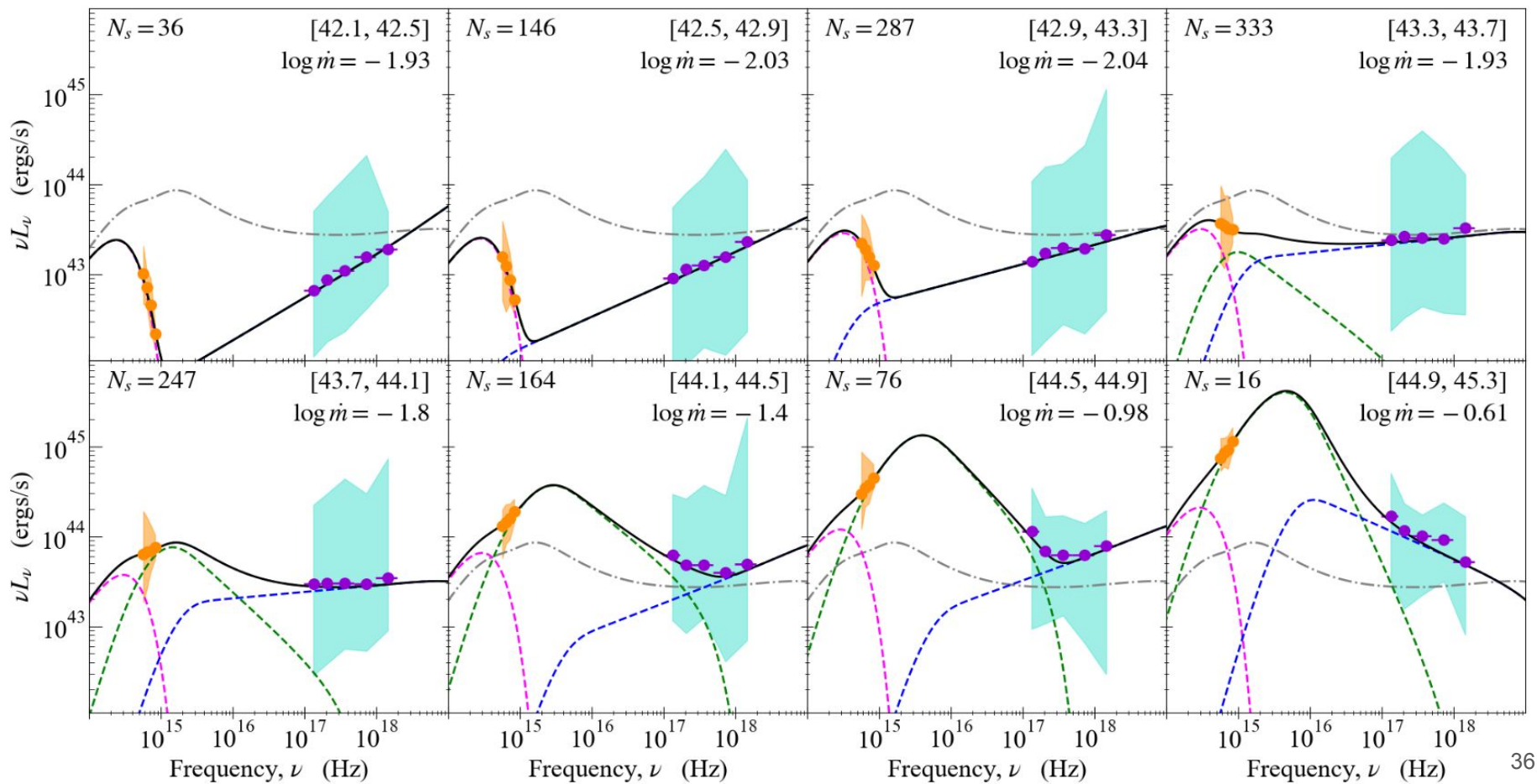
**Hagen & Done (2023a)** - AGN variability

**Hagen & Done (2023b)** - AGN SEDs and GR

**Mitchell..SH..et al. (2023)** - AGN SEDs in large samples

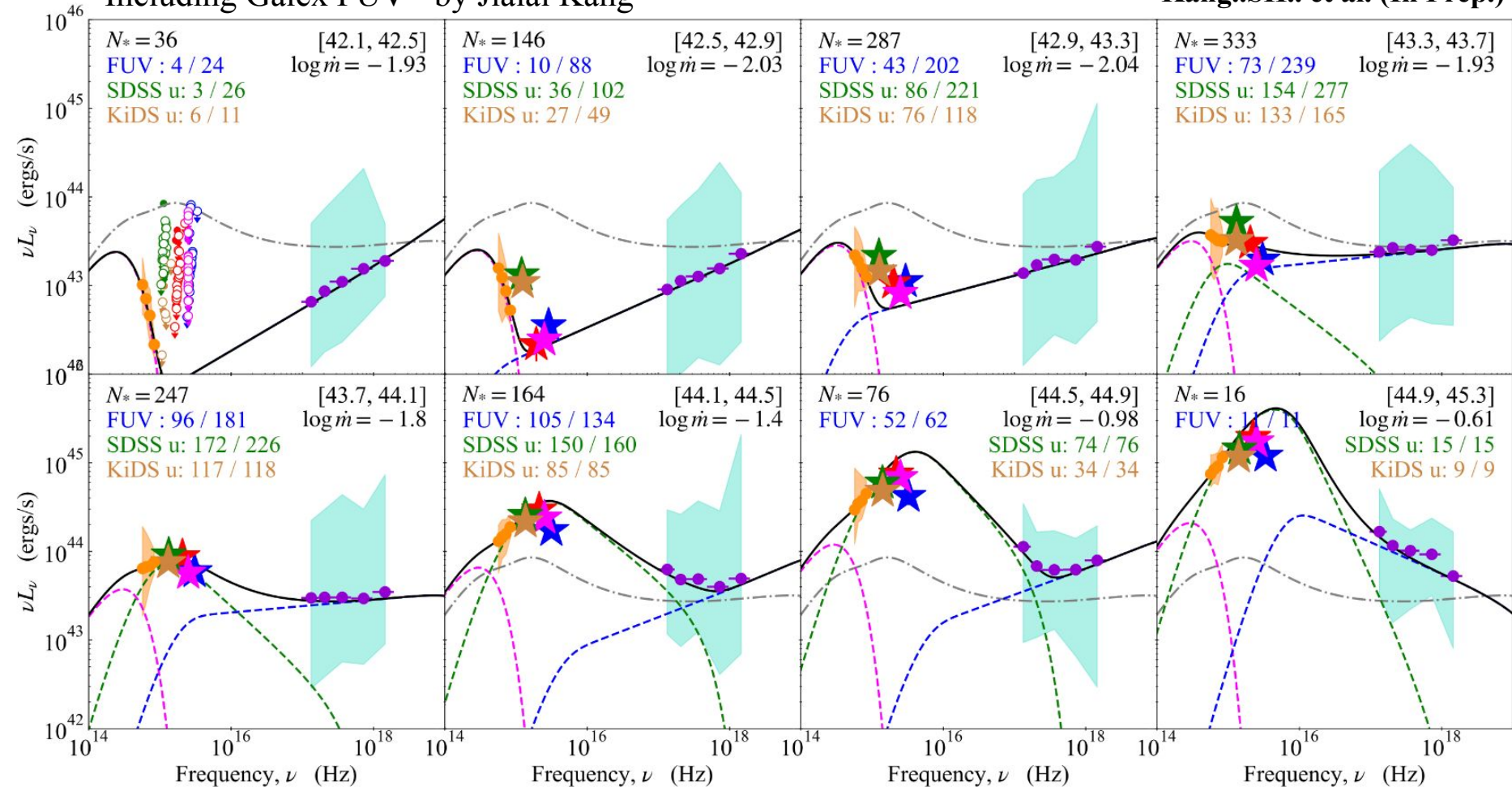
**Hagen, Done & Edelson (2024)** Detailed AGN variability

# Backup Slides



## Including Galex FUV - by Jialai Kang

Kang..SH.. et al. (In Prep.)



# Identifying AGN through Broad Lines

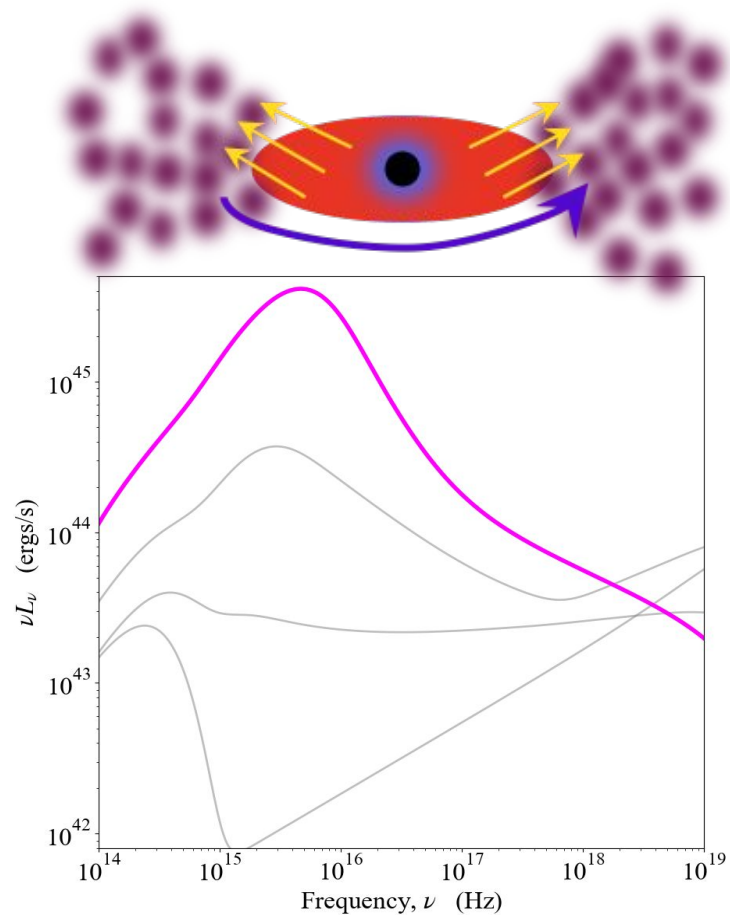
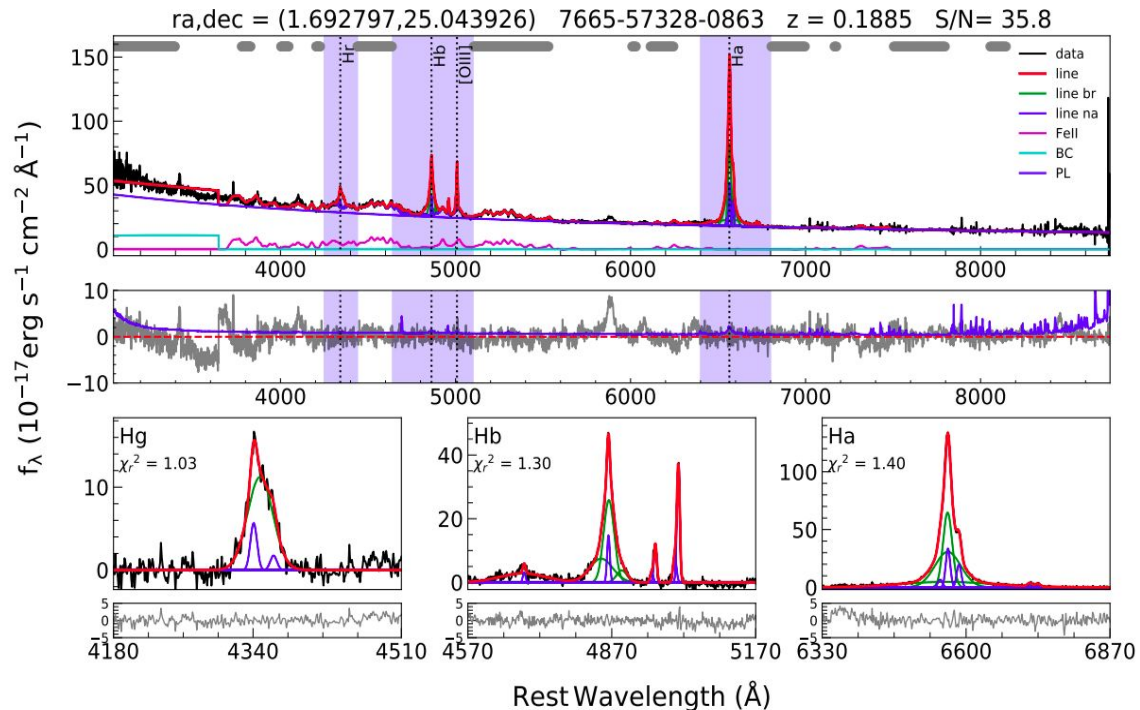
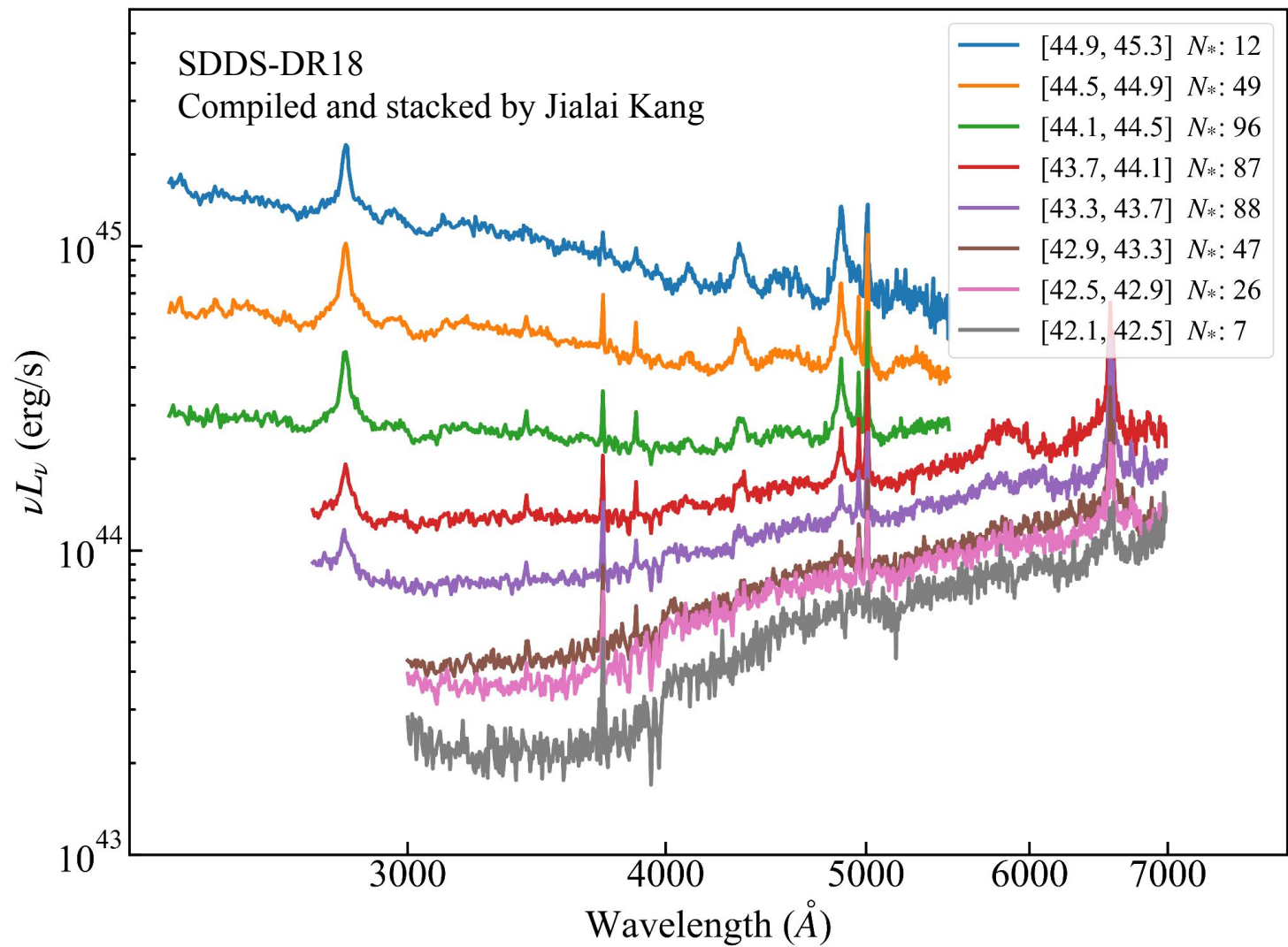
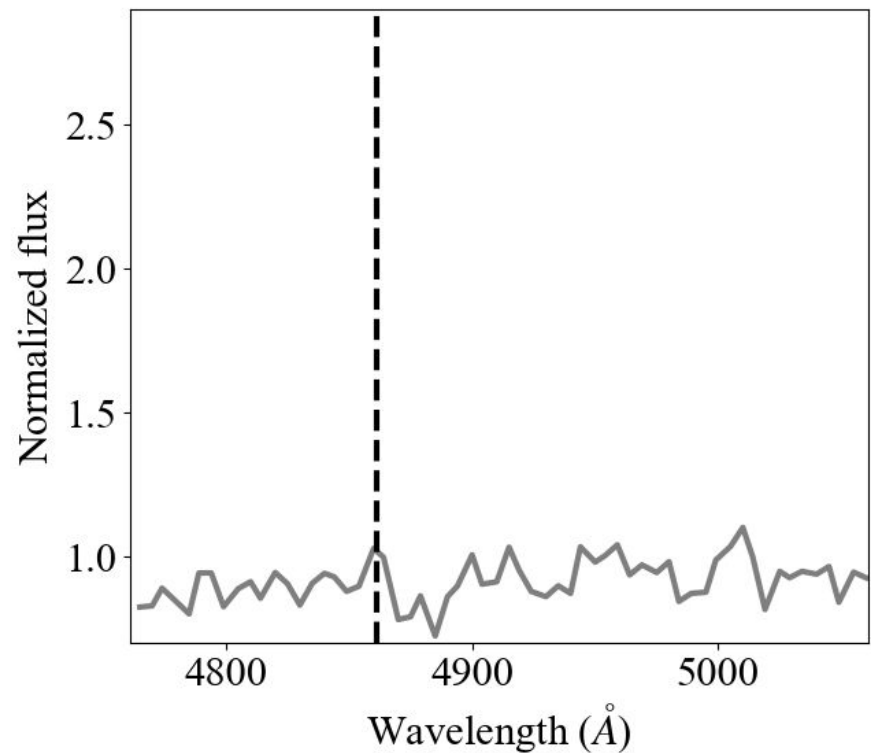
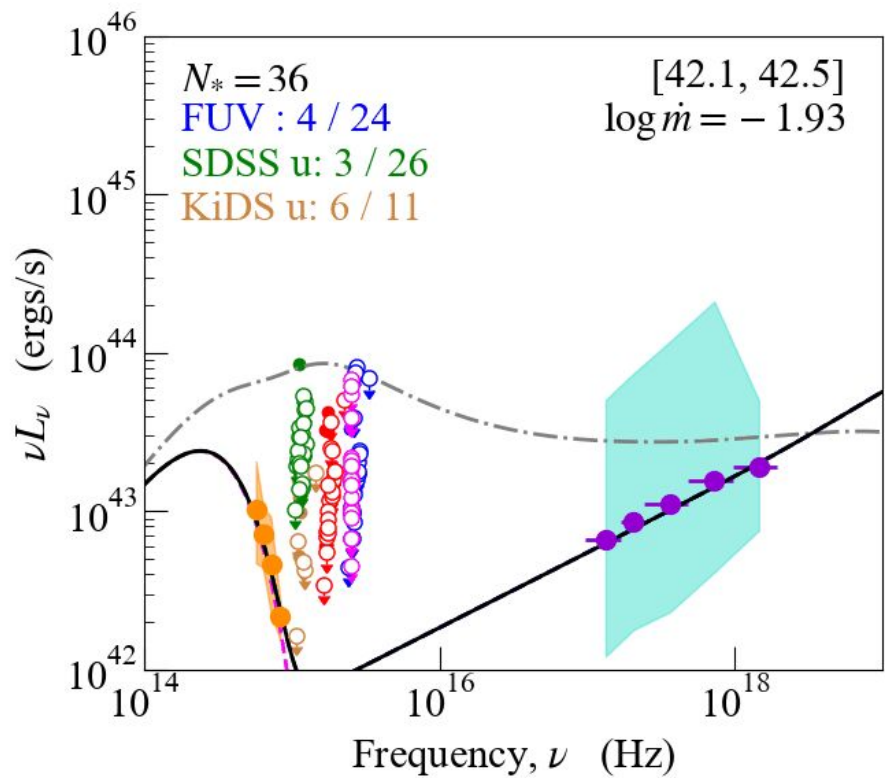


Figure taken from: **Rakshit et al. 2020**



- Broad-lines induced by EUV emission in the SED
- Predict the loss of the broad-line emission as the disc collapses







There is NO disc at low mass accretion rates!!

