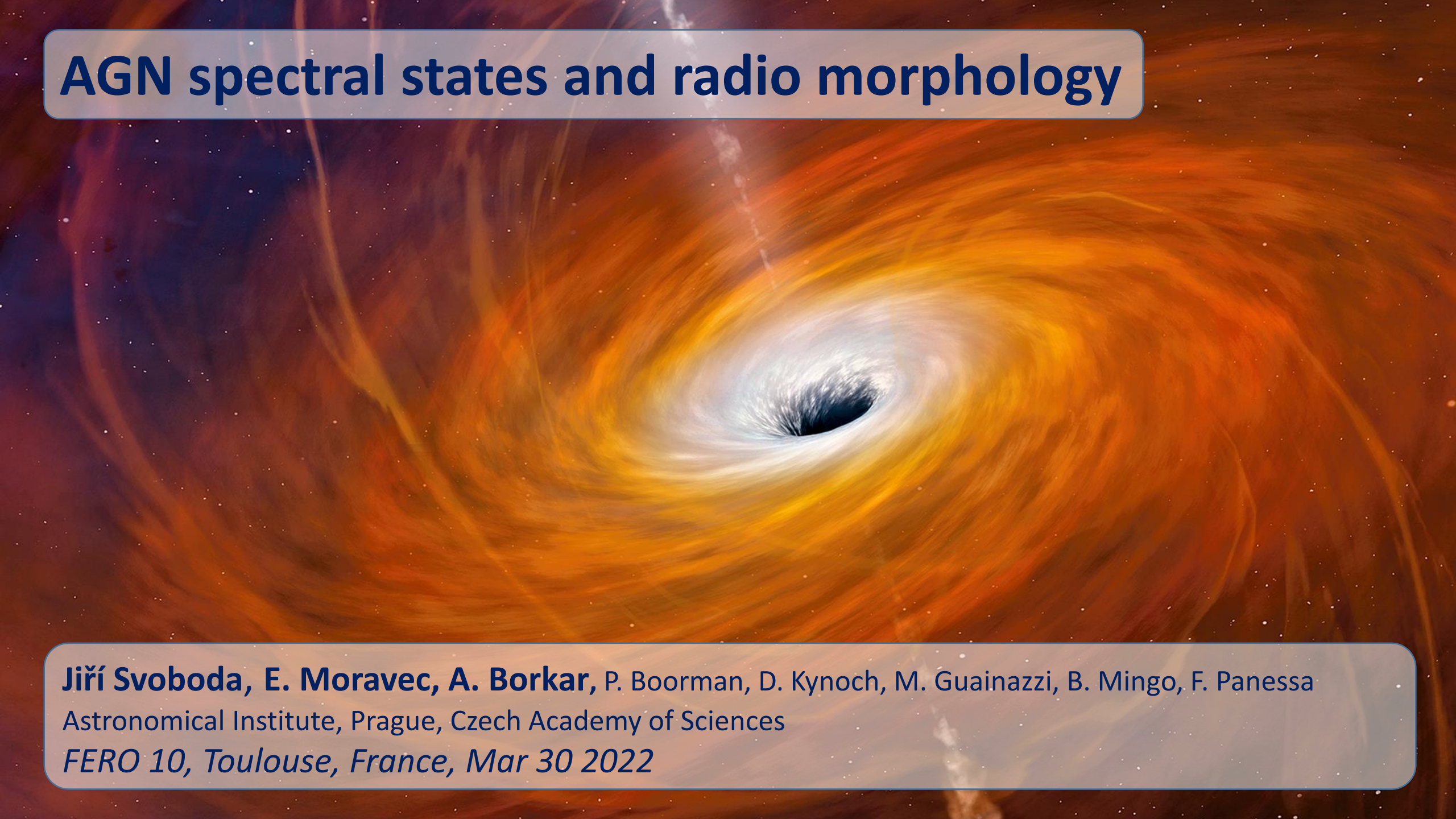
AGN spectral states and radio morphology



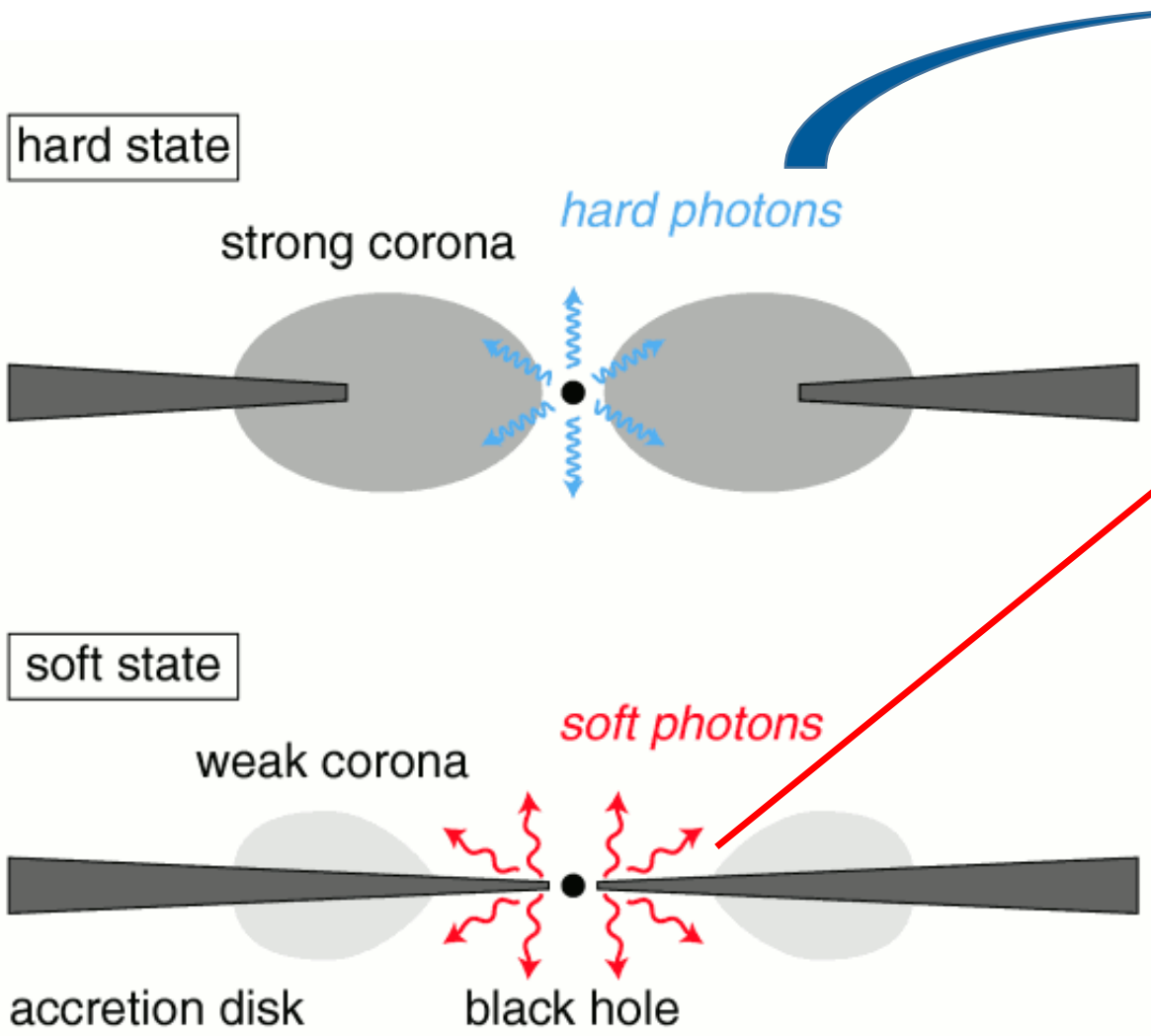
Jiří Svoboda, E. Moravec, A. Borkar, P. Boorman, D. Kynoch, M. Guainazzi, B. Mingo, F. Panessa
Astronomical Institute, Prague, Czech Academy of Sciences

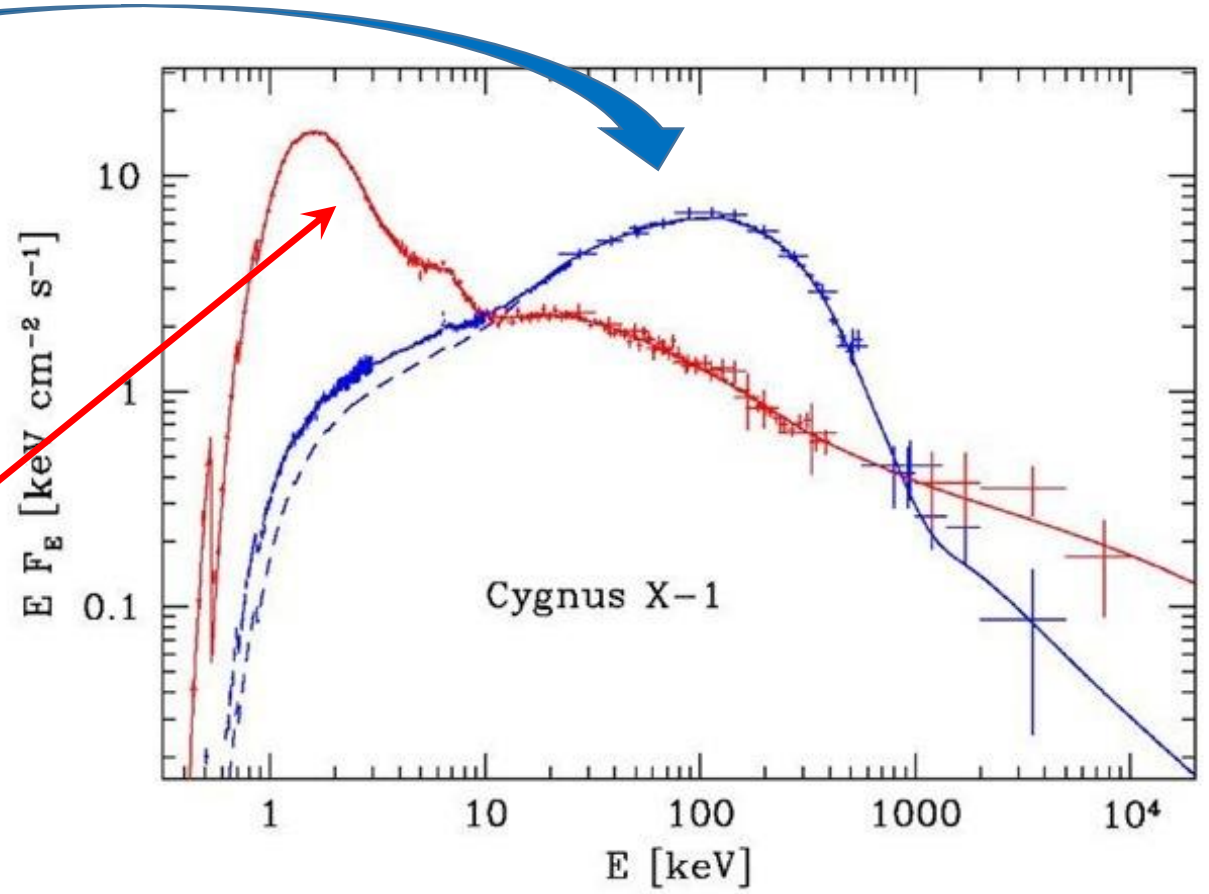
FERO 10, Toulouse, France, Mar 30 2022


May 2018, FERO9, Heraklion, Crete

Accreting black holes

X-ray Binaries: spectral states

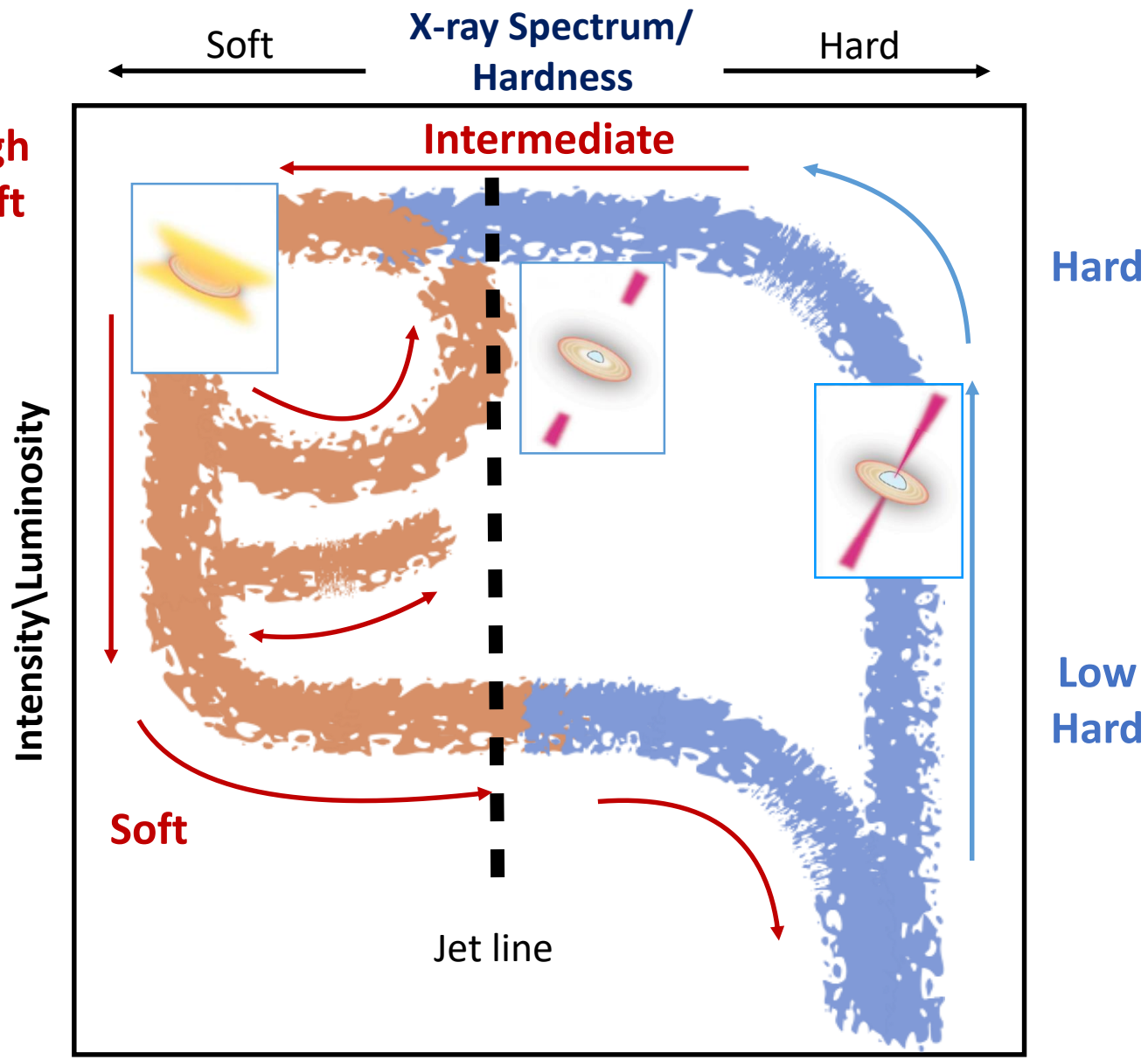




for more details see, e.g., Gierlinski+99, Zdziarski+04, Remillard & McClintock 06, Done+04,07, Zycki+01, Meyer-Hofmeister+05,... ***Chris Done's talk this morning***

Evolution of spectral states in XRBs

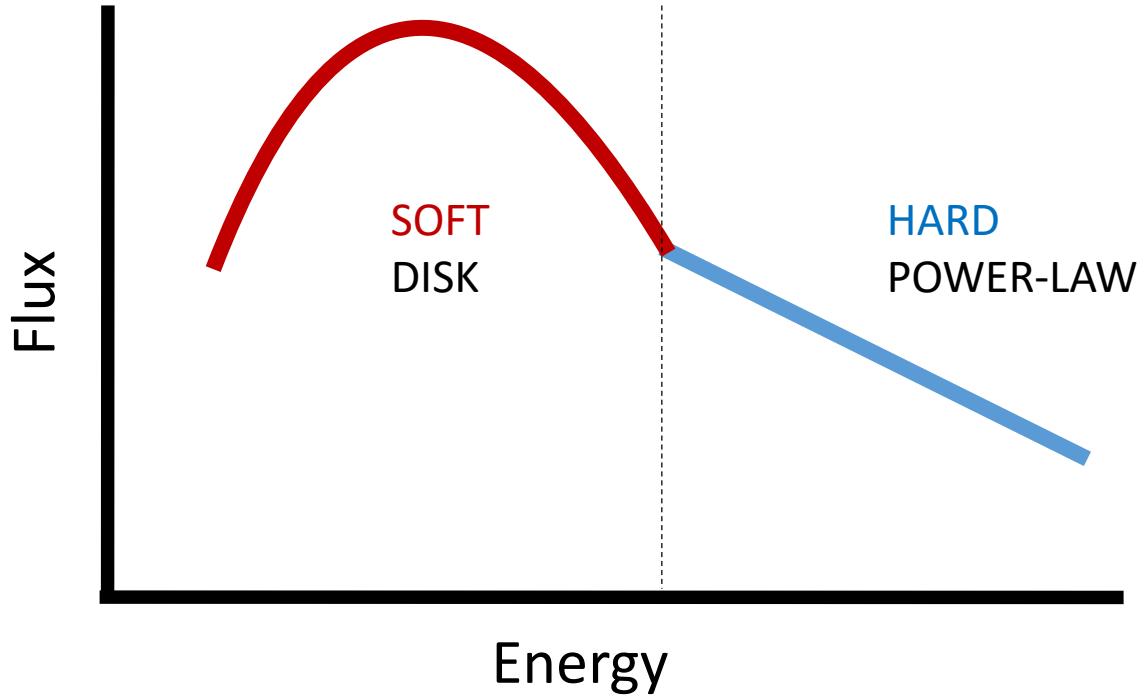
- transition from the hard to soft happens at higher luminosity than the transition from the soft to hard
- jet is present only in the hard states
- for theoretical explanations see, e.g.: Chakrabarti & Titarchuk 95, Smith+ 02, Liu+ 05, Petrucci+ 08, Contopoulos+ 15



Based on Fender+ 04, 12

Analogy of spectral states in AGN?

- different size & time scale
- study of a **large sample** & **multiwavelength analysis**
  - previous works: Merloni+ (2003), Falcke+ (2004), Körding+ (2006), McHardy+(2006), Sobolewska+ (2011),...

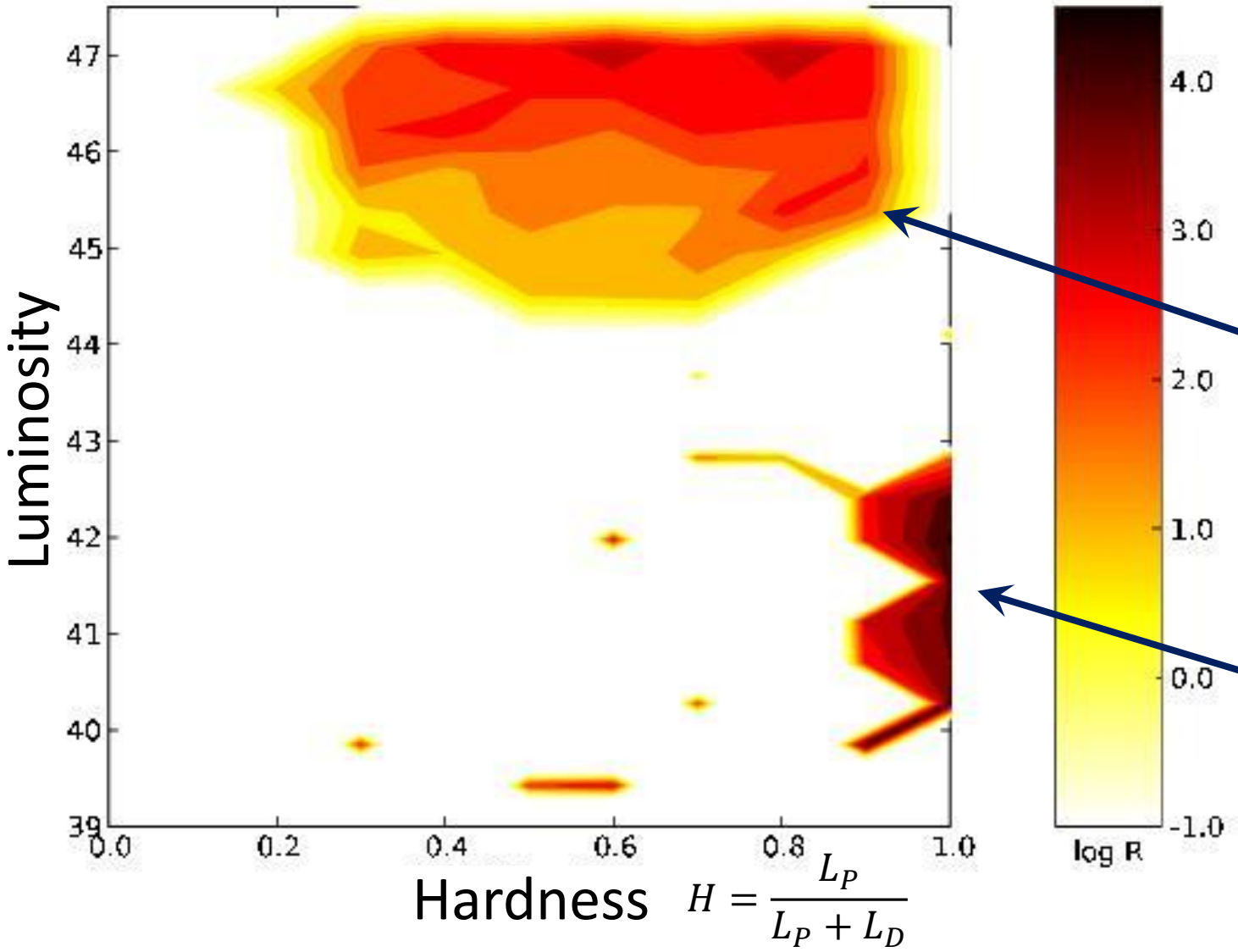


Spectral Hardness:

$$\frac{L_{\mathrm{X}}}{L_{\mathrm{tot}}} \approx \frac{L_{\mathrm{PL}}}{L_{\mathrm{PL}} + L_{\mathrm{disk}}}$$

$\approx L_{\mathrm{optical}}$

AGN spectral states – previous works

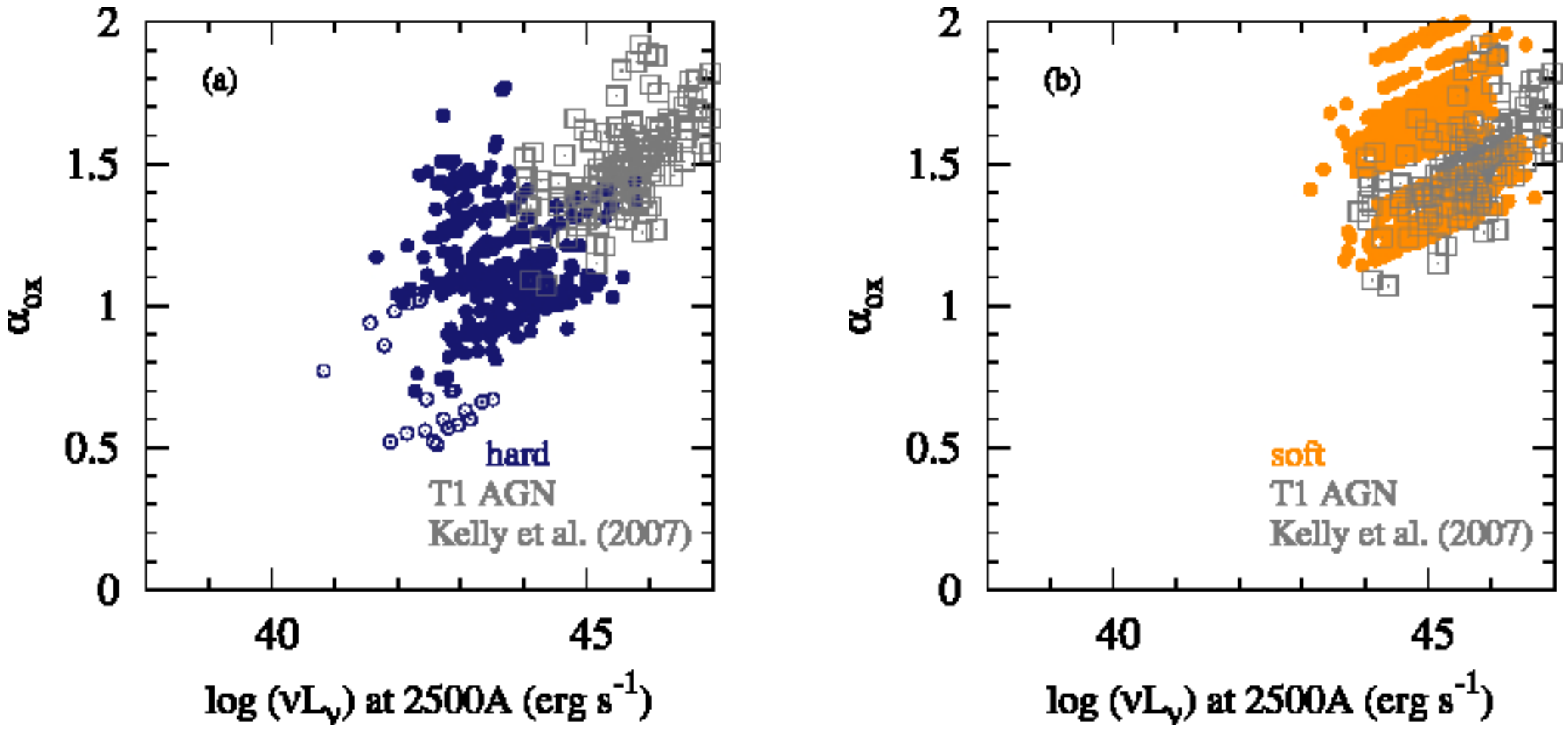


Koerding et al. (2006a)

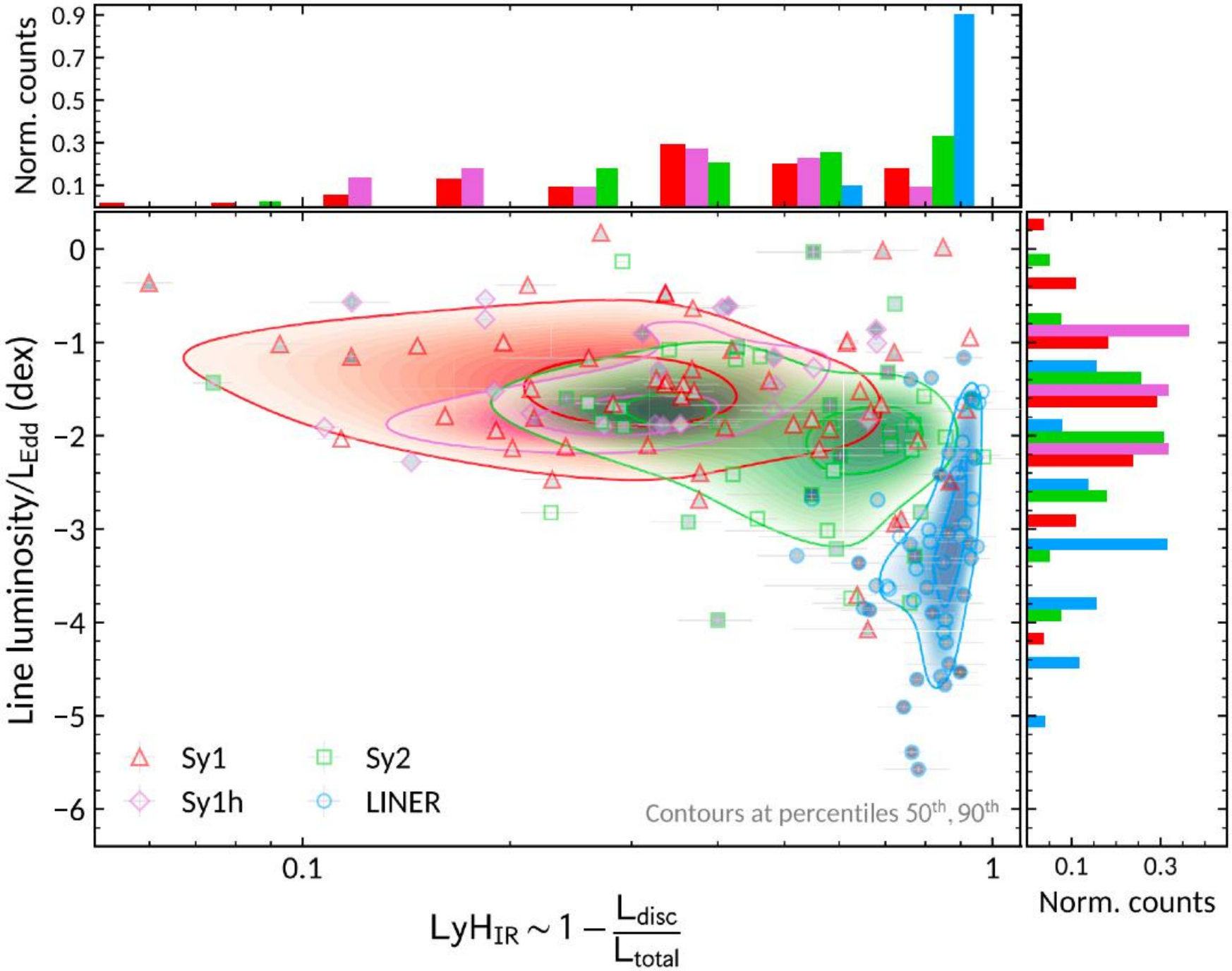
sample based on SDSS (optical), ROSAT (X-rays) and FIRST (radio)

low-luminosity AGN taken from Ho et al. 97

Relation between AGN type and spectral state



Sobolewska et al. (2011)



Fernández – Ontiveros & Muñoz – Darias (2021):

For spectral hardness use Lyman hardness:

$$LyH_{IR} = \frac{[\mathrm{Ne\ II}]}{[\mathrm{Ne\ II}]+[\mathrm{O\ IV}]}$$

Analogy of spectral states in AGN?

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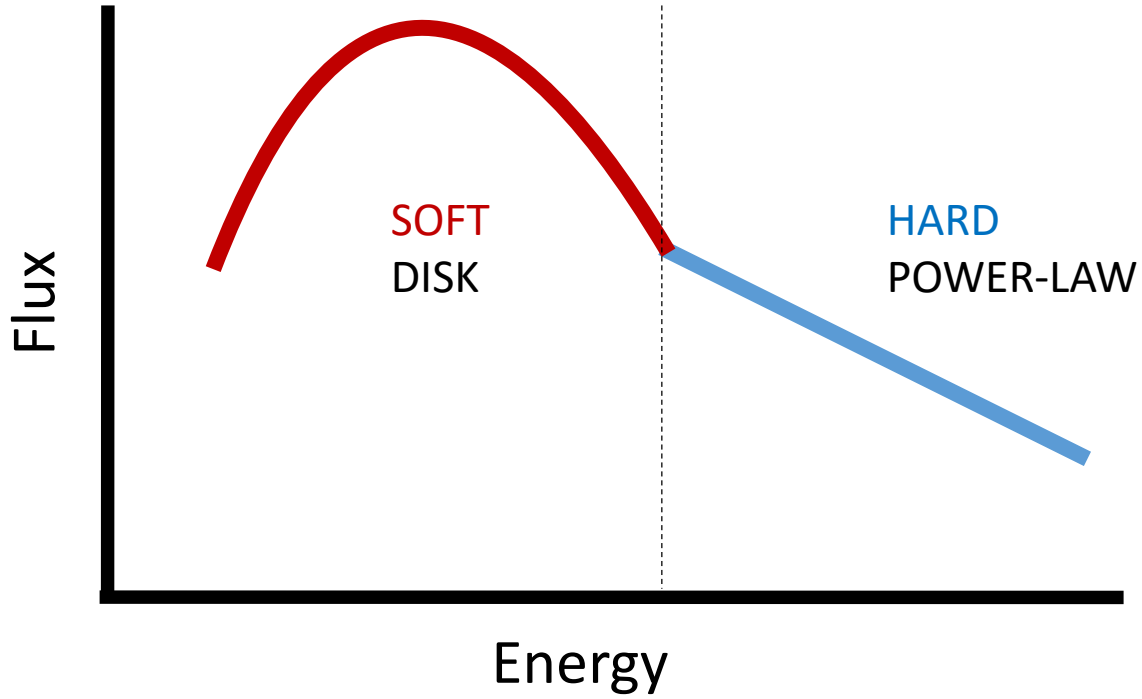
- study of a **large sample** & **multiwavelength analysis**
  - previous works: Merloni+ (2003), Falcke+ (2004), Körding+ (2006), McHardy+(2006), Sobolewska+ (2011),...



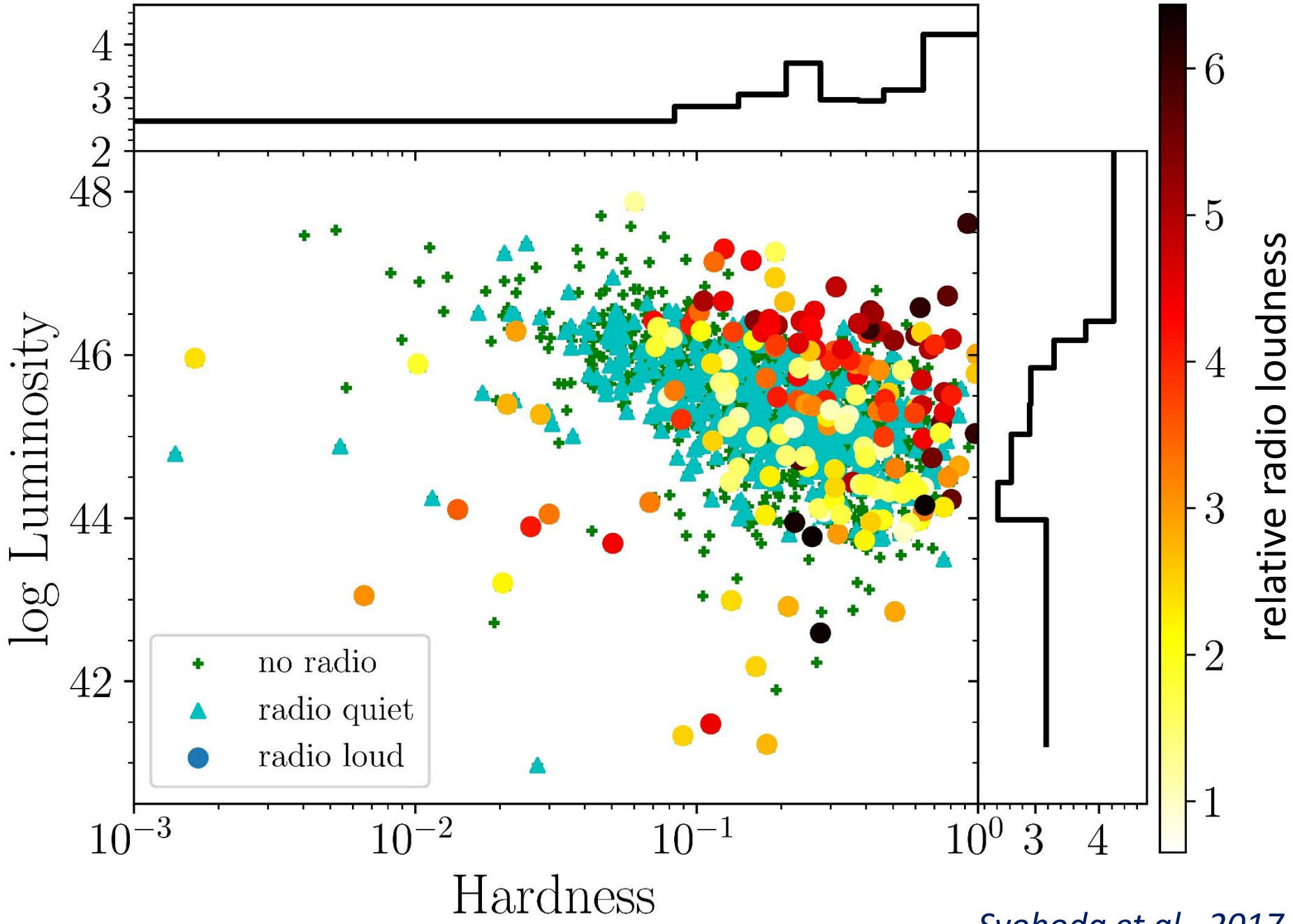
Spectral Hardness:

$$\frac{L_{\mathrm{X}}}{L_{\mathrm{tot}}} \approx \frac{L_{\mathrm{PL}}}{L_{\mathrm{PL}} + L_{\mathrm{disk}}} \approx \frac{L_{\mathrm{X}}}{L_{\mathrm{X}} + L_{\mathrm{UV}}}$$

for AGN

Hardness – Luminosity diagram for AGN

UV + X-ray simultaneous observations by XMM-Newton



Svoboda et al., 2017

Hardness – Luminosity diagram for AGN

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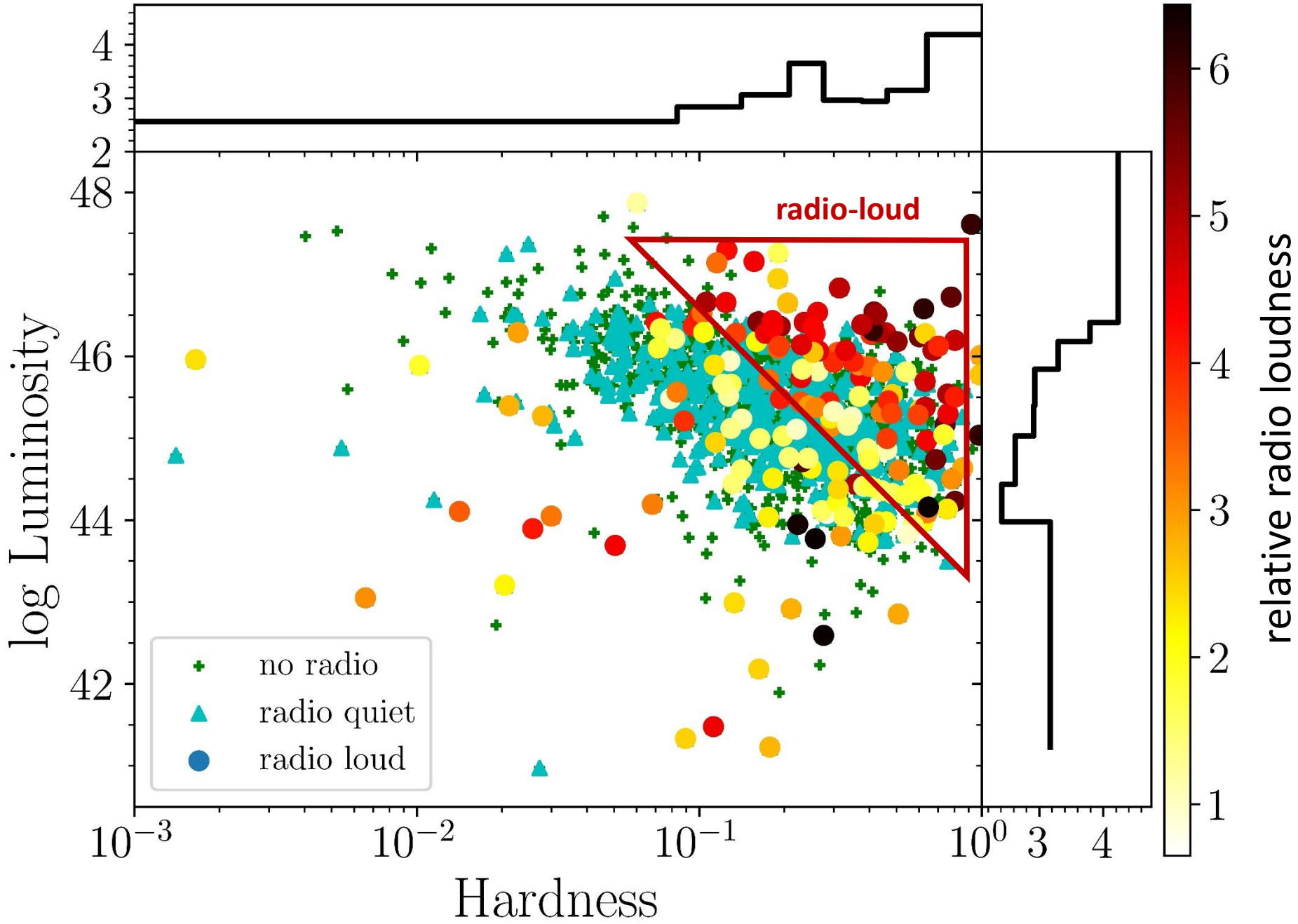
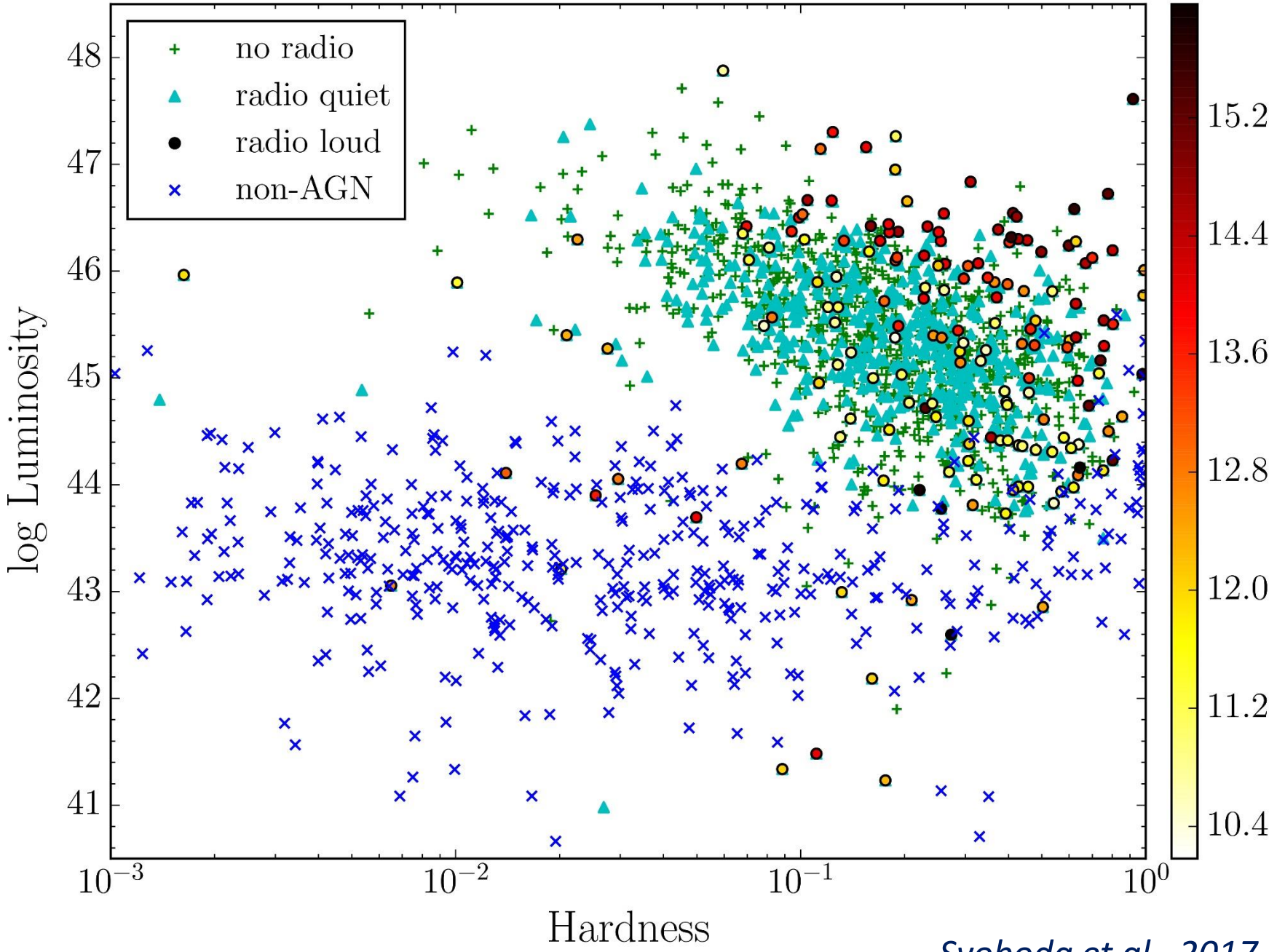


Svoboda et al., 2017

Low – luminosity sources

- problem with the **host-galaxy contamination**
- **non-AGN** show ``distribution of host galaxies'' in the diagram

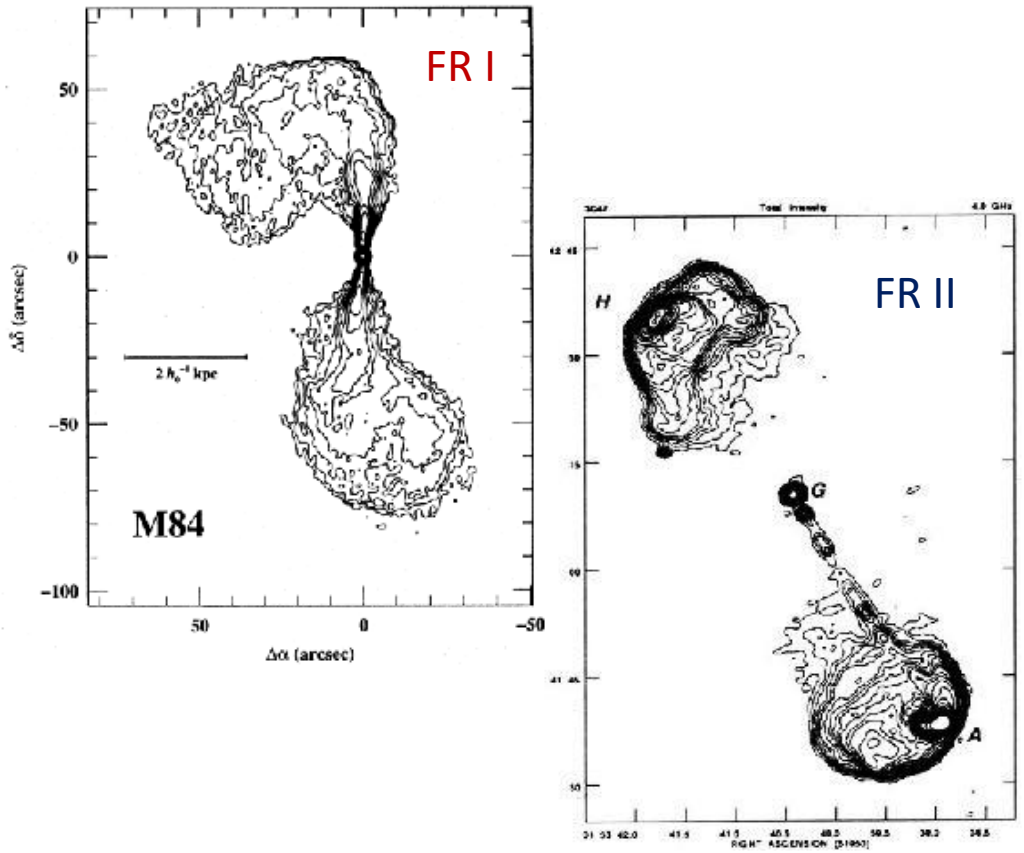


Svoboda et al., 2017

Radio-AGN properties

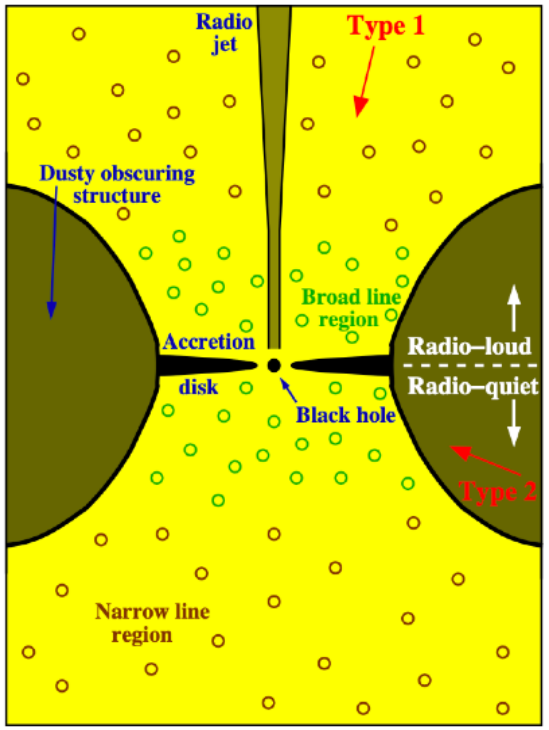
radio morphology

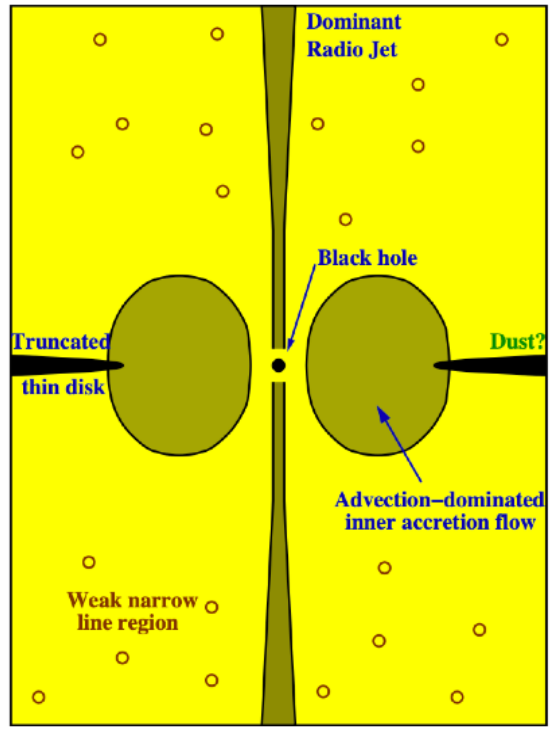
Fanaroff-Riley classification:



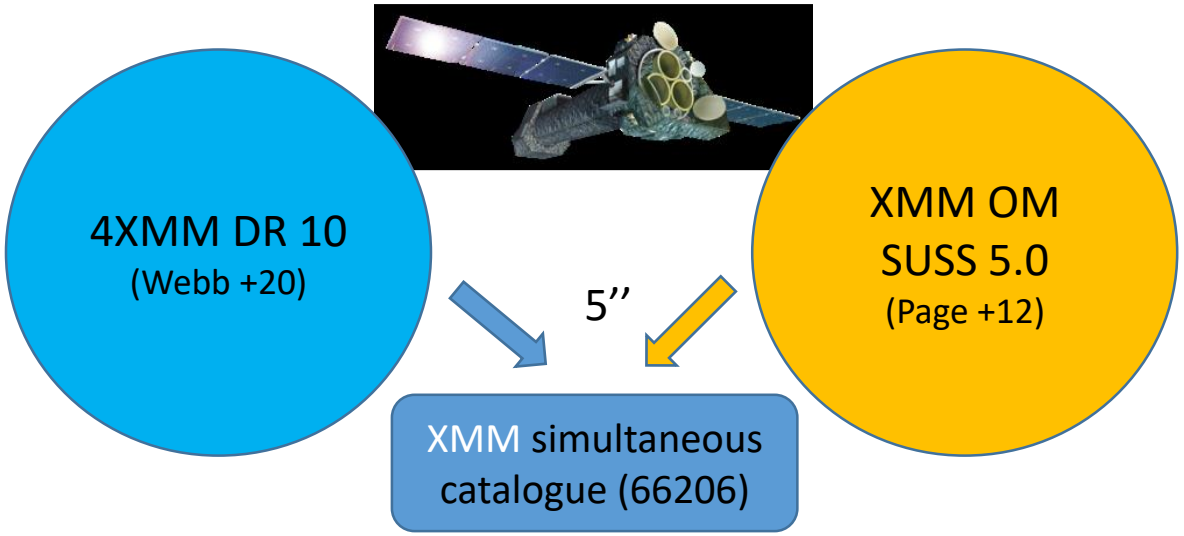
excitation class

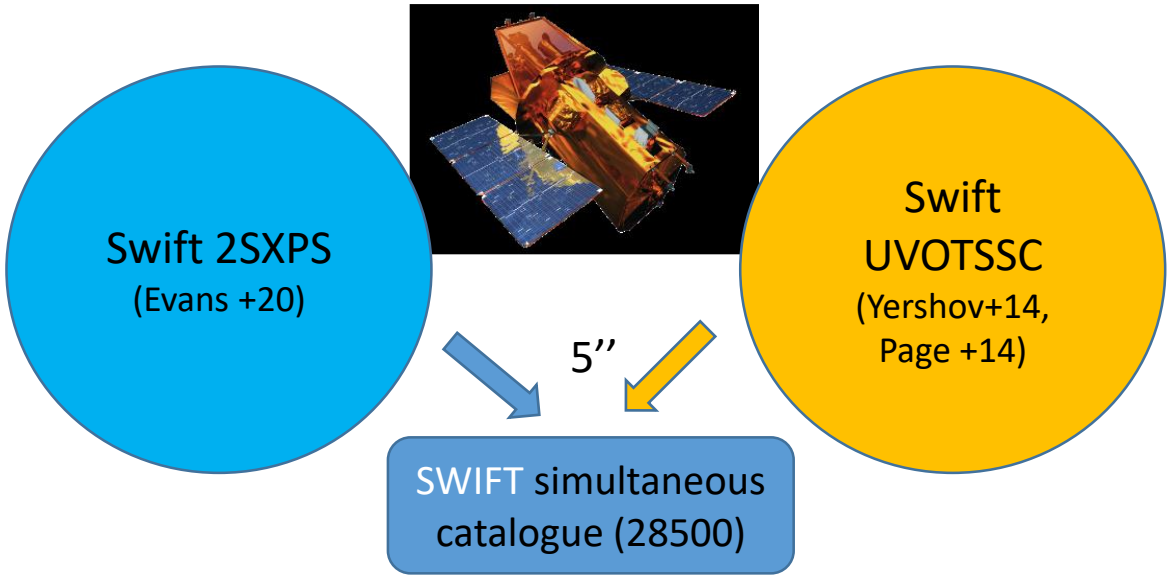
low vs. high excitation (optical lines) radio galaxies





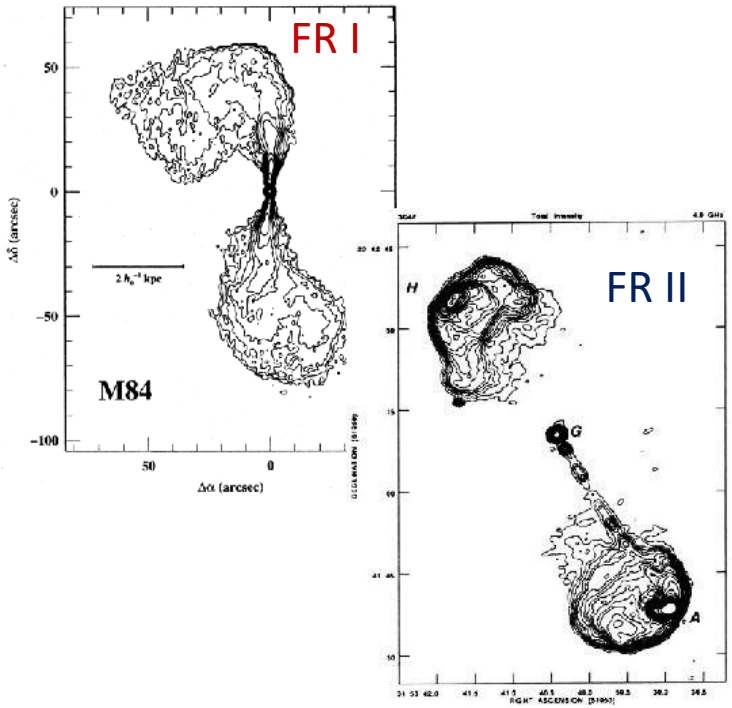
Sample of radio-AGN with X-ray and UV observations



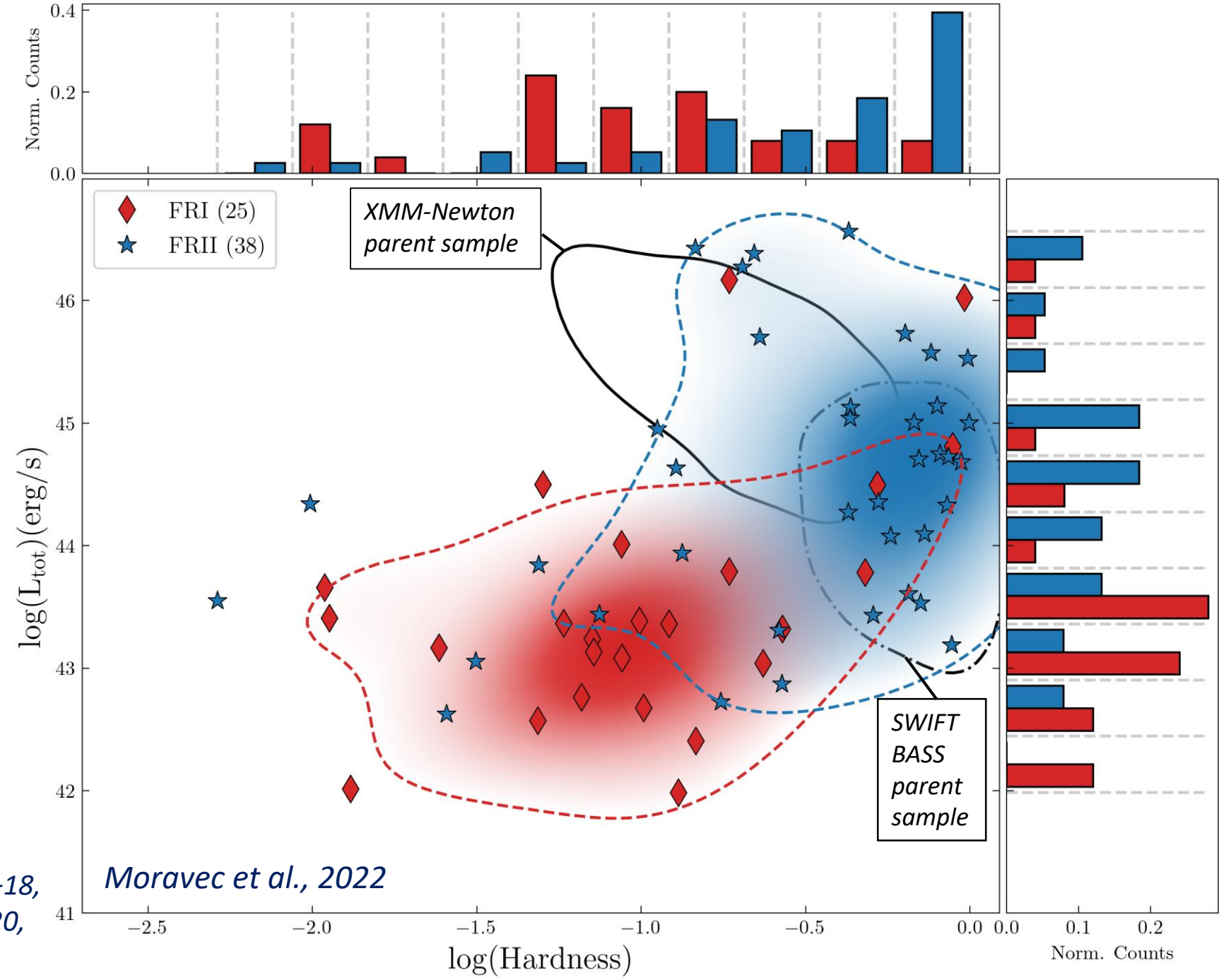


Radio morphology

Fanaroff-Riley classification:



radio morphology catalogues used:
Gendre+10, Capetti+17, Miraghei+17, Baldi+18, Jimenez-Galardo+19, Mingo+19, Dabhade+20, Macconi+20, Koziel-Wierzbowska+20



Radio morphology

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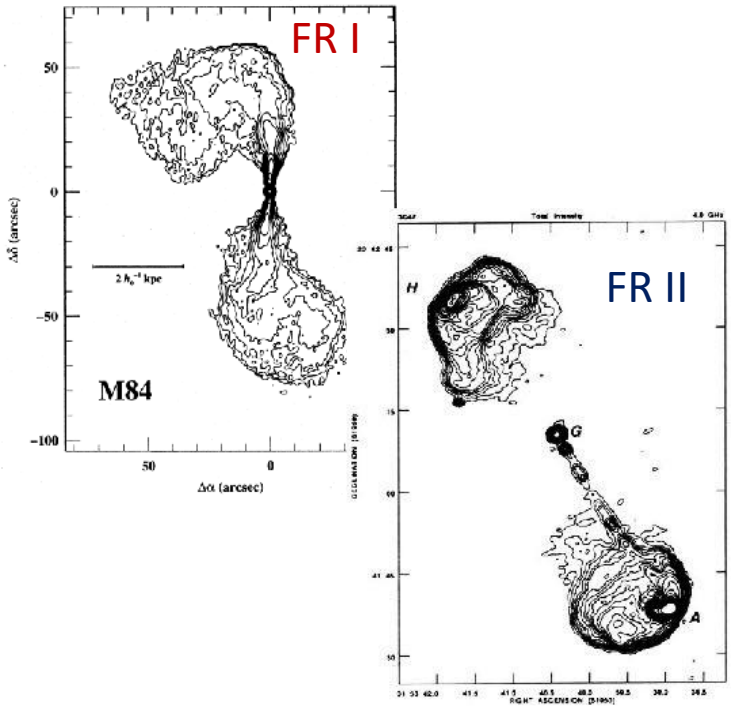

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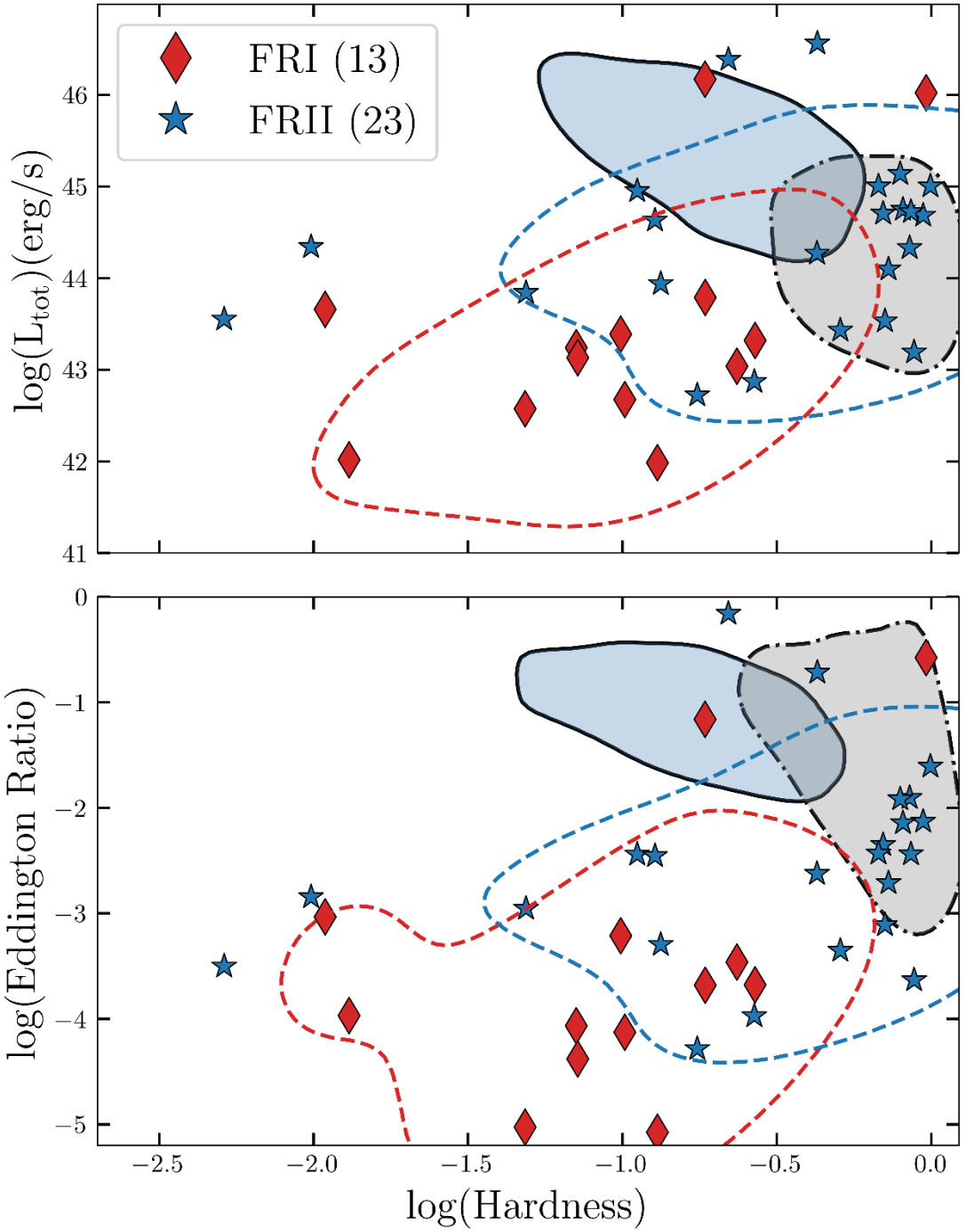


*Comparison of **Luminosity** and **Eddington ratio** for sources with known mass*

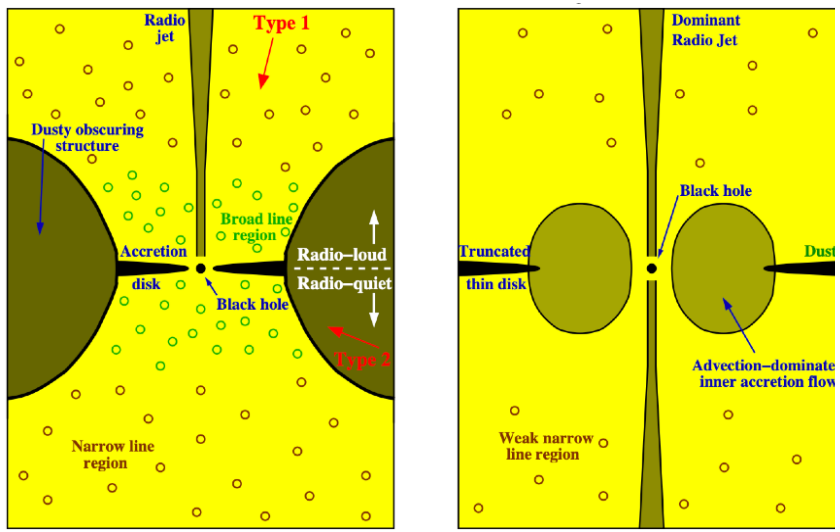
Moravec et al., 2022

Excitation

Excitation classification:

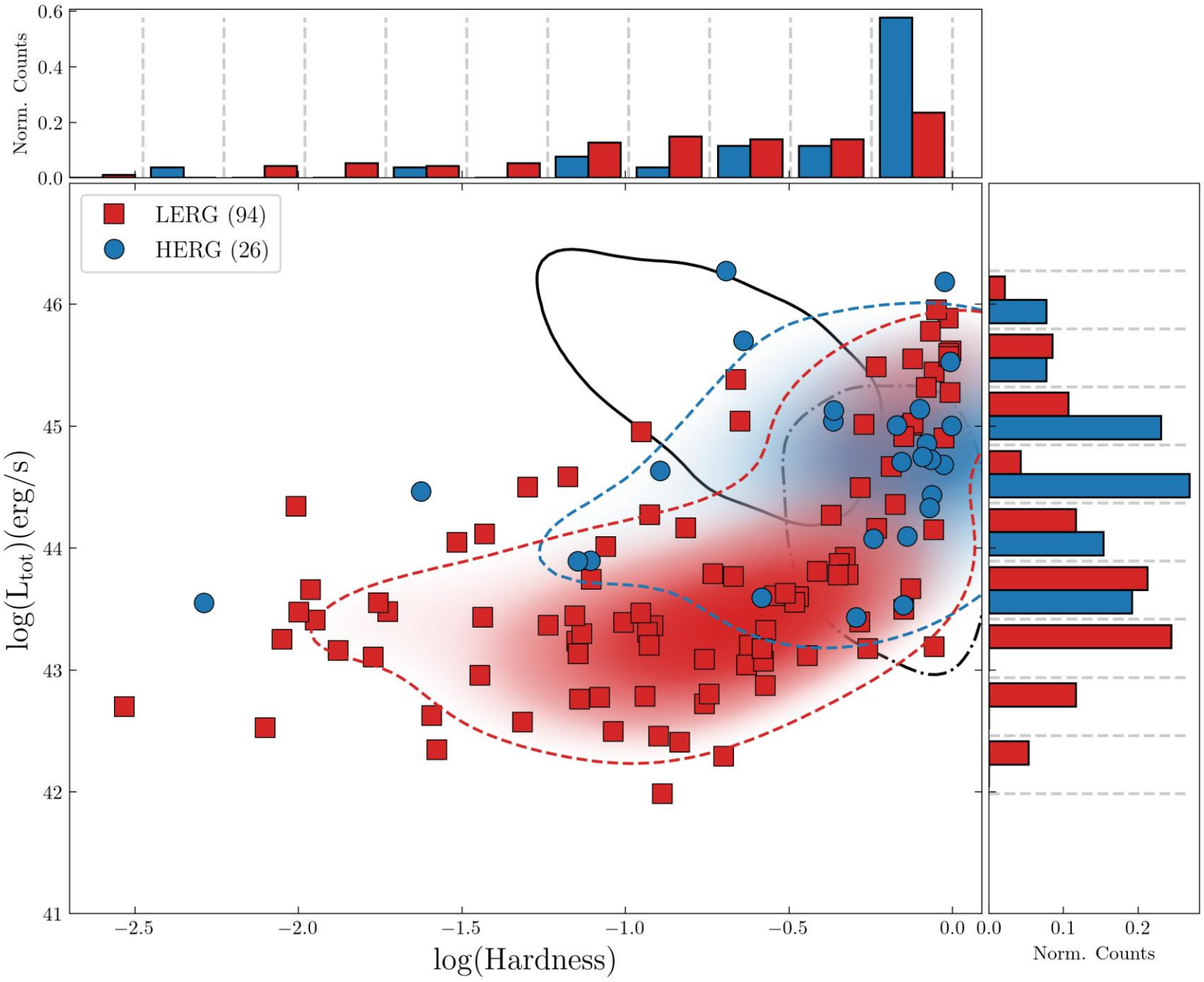
HERG: High Excitation Radio Galaxy

LERG: Low Excitation Radio Galaxy



Heckman & Best, 2014

catalogues used:
Best & Heckman+12, Ching+17

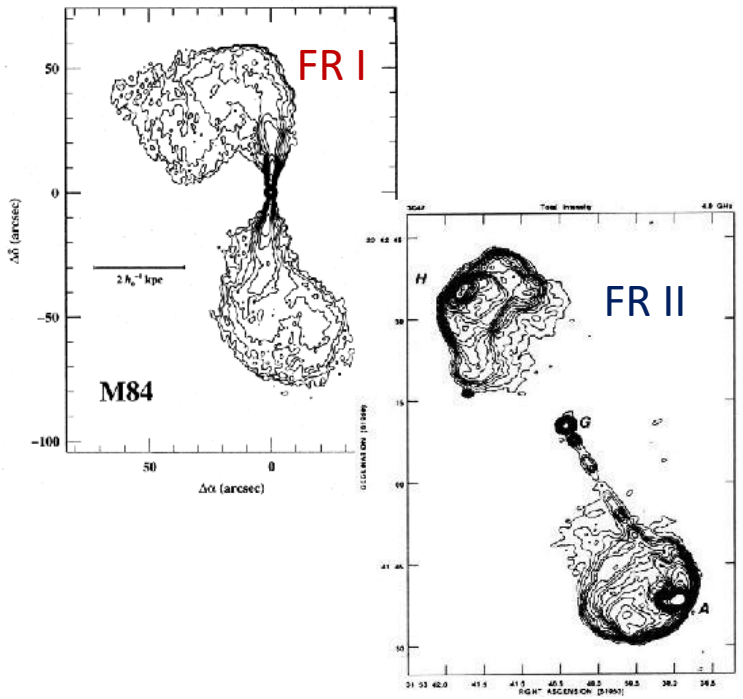


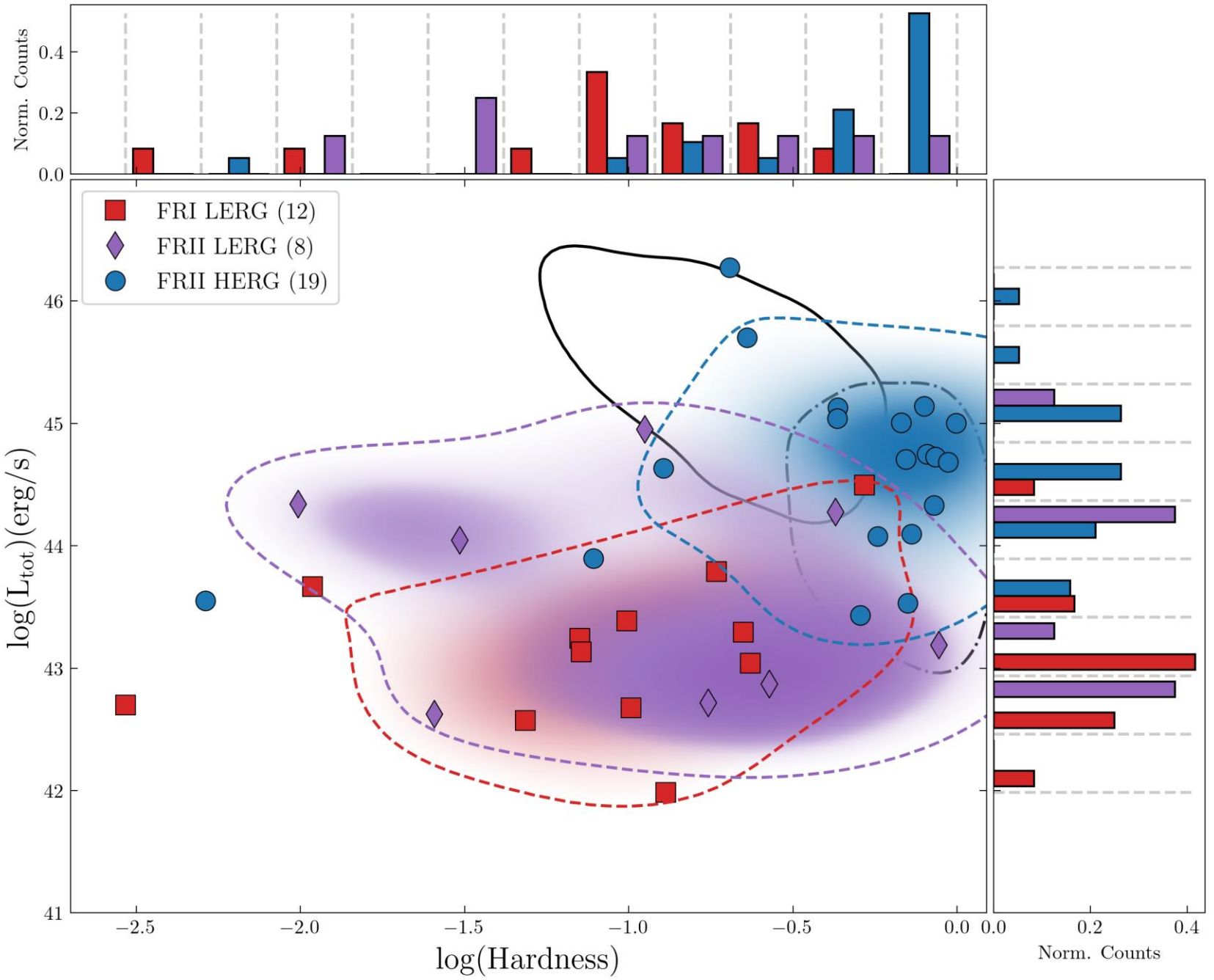
Moravec et al., 2022

Radio Morphology + Excitation

HERG: High Excitation Radio Galaxy

LERG: Low Excitation Radio Galaxy



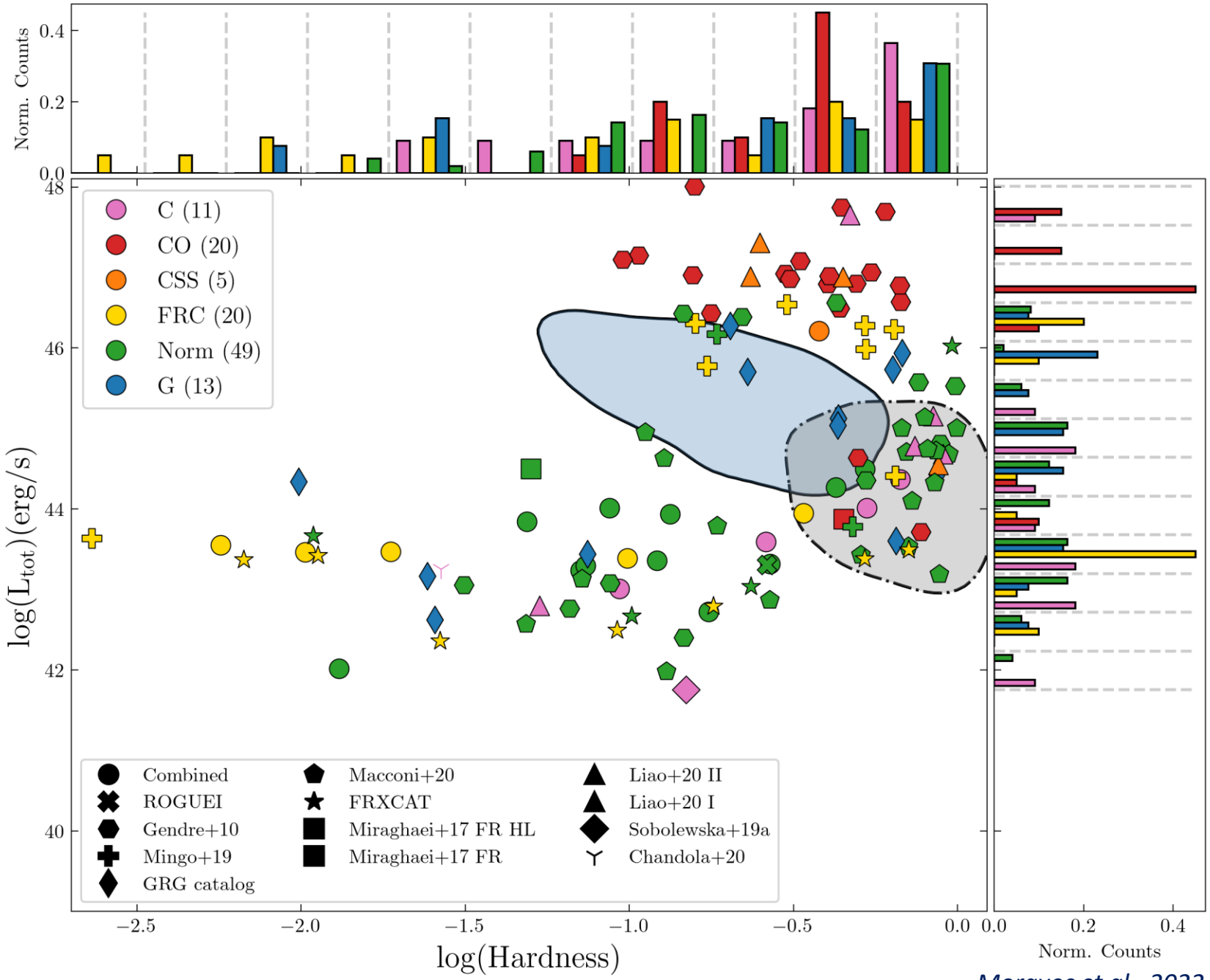


Moravec et al., 2022

Radio extent

C, CO, CSS, FRC: compact
< 1 kpc

G: giant
> 0.7 Mpc



Moravec et al., 2022

Conclusions

- we have studied AGN with radio morphology and compared their position in the hardness-intensity diagram (analogical spectral state diagram to XRBs)
  - galaxies with different radio morphology / excitation characteristics occupy different places in the hardness-intensity diagram
- does it indicate that the AGN radio activity and morphology is affected by the spectral state evolution similar to XRB?
- more details in paper Moravec et al. (2022)

Thank you for your attention!!!

Future prospects on AGN spectral states

- key ingredients for the study:
    - mass (reverberation techniques, virial masses)
    - X-ray luminosity, X-ray spectral slope
    - UV luminosity (not contaminated by host galaxy), UV spectral slope
    - radio luminosity
    - radio morphology or radio spectral shape
        - new **more-sensitive radio surveys** (LOTSS, VLASS, SKA)
- large homogeneous sample
    - eROSITA, ATHENA/WFI surveys with complementary surveys by instruments at other wavelengths