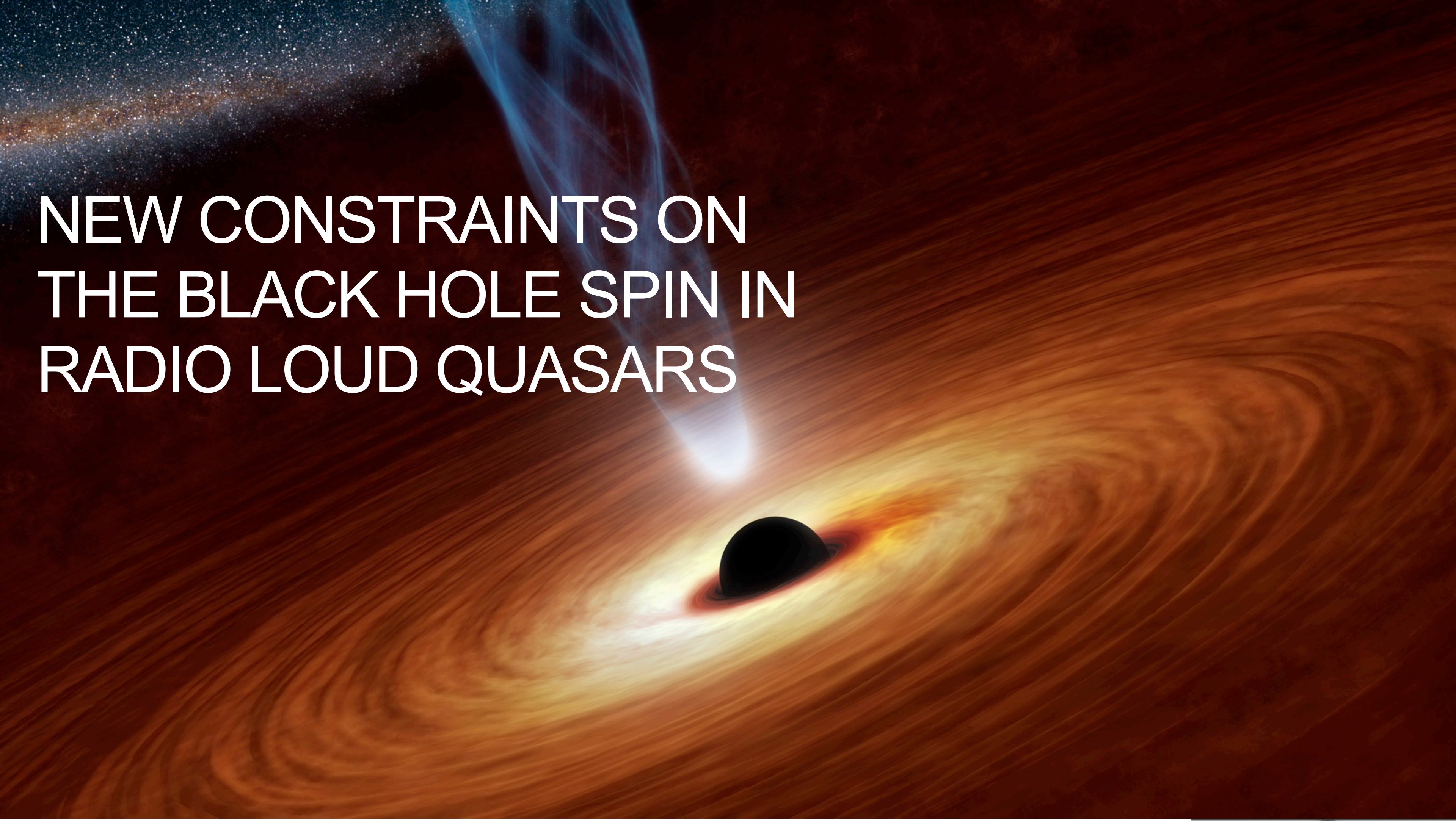
NEW CONSTRAINTS ON THE BLACK HOLE SPIN IN RADIO LOUD QUASARS



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East Asian Young Astronomers Meeting, EAYAM 2017

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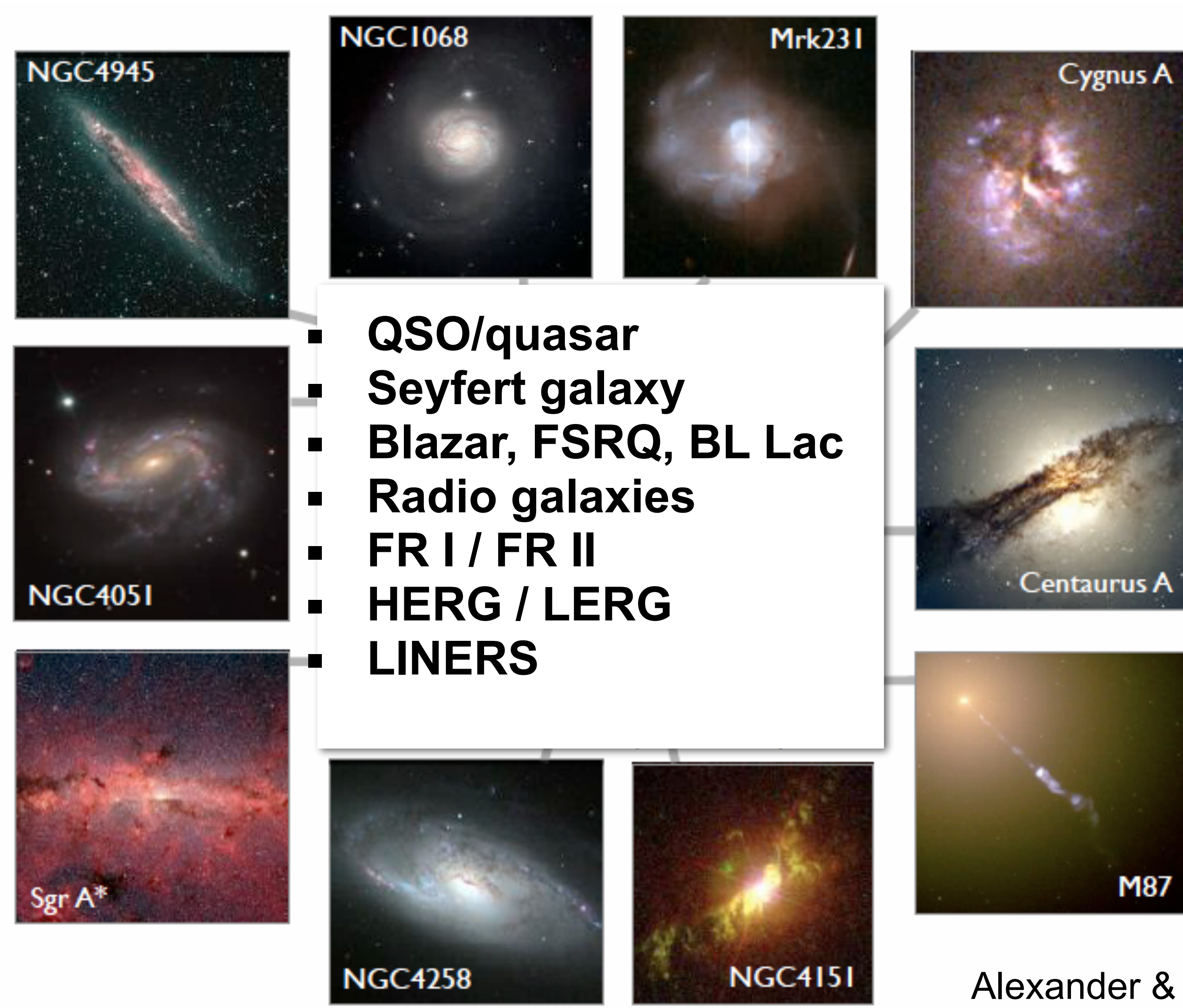
Active Galactic Nuclei (AGN) Zoo



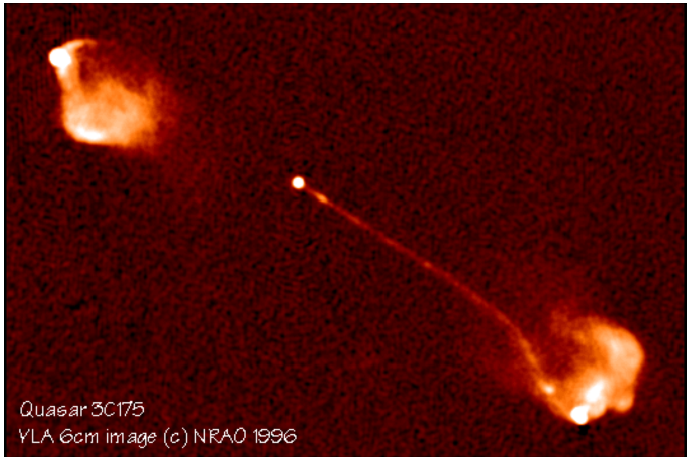
- **QSO/quasar**
- **Seyfert galaxy**
- **Blazar, FSRQ, BL Lac**
- **Radio galaxies**
- **FR I / FR II**
- **HERG / LERG**
- **LINERS**

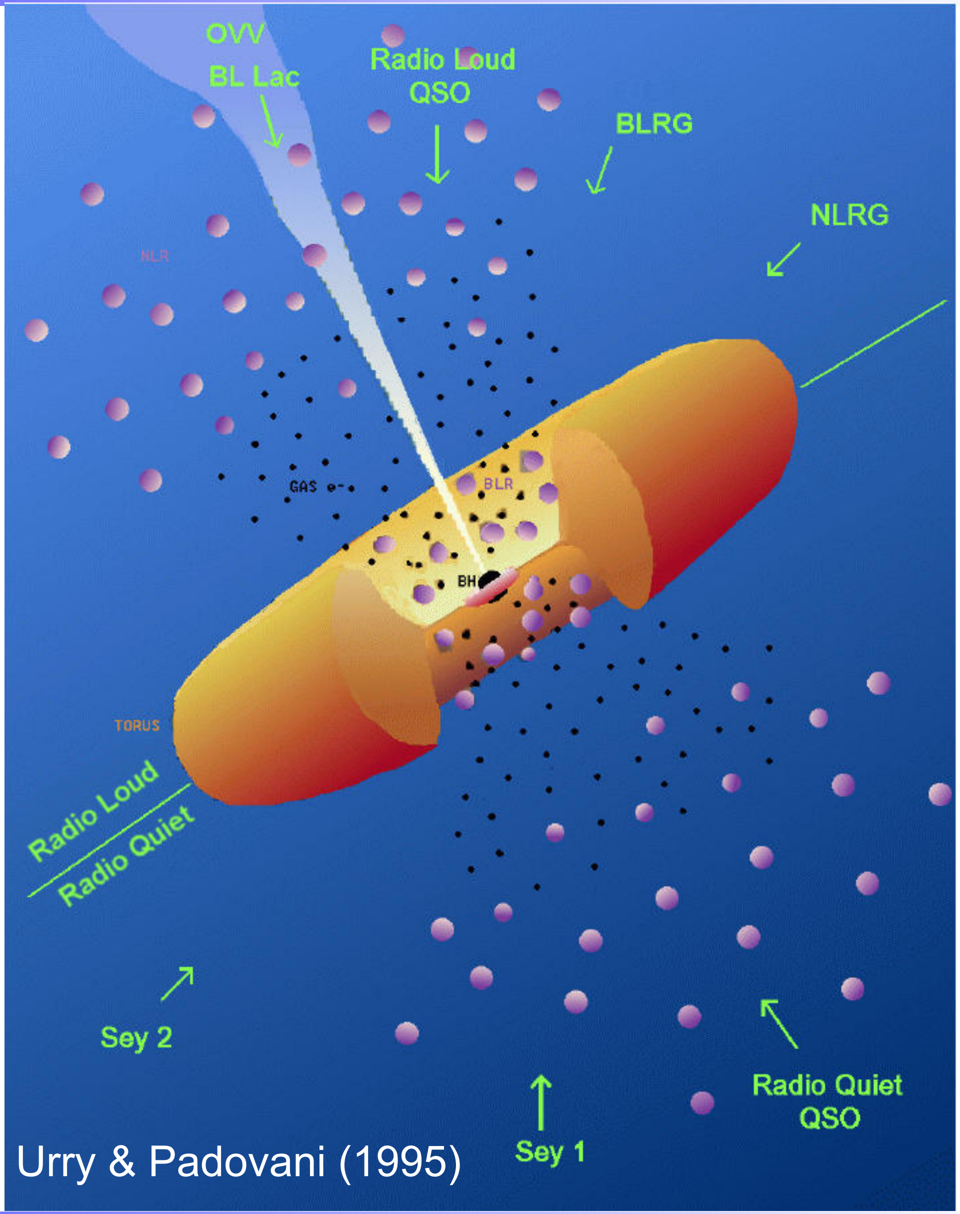
Alexander & Hickox (2012)

AGN Unification: Radio properties?

What causes AGN to be radio-loud (RL) or radio quiet (RQ) / have relativistic jets?

- Black hole mass M_{BH}
- Eddington ratio $\lambda = L_{bol} / L_{edd}$
- BH spin



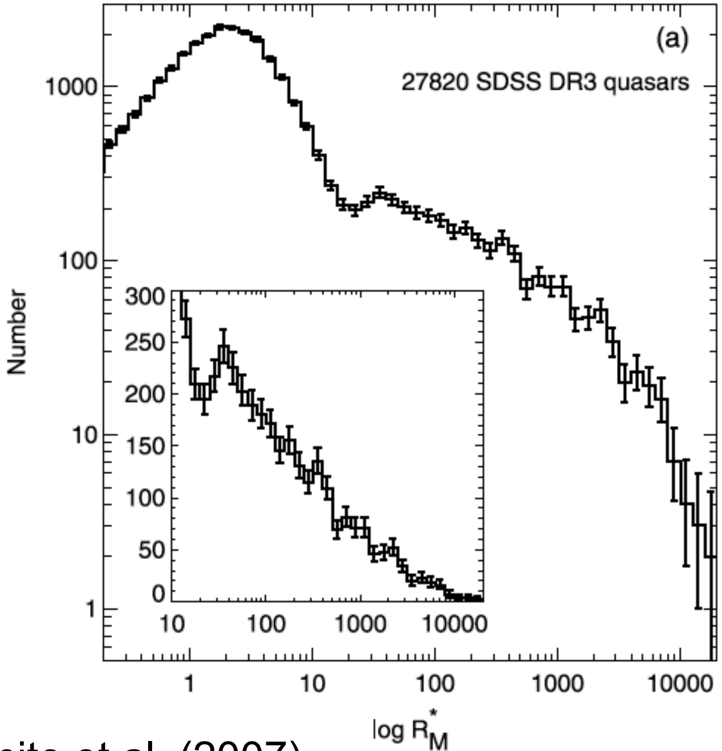


Urry & Padovani (1995)

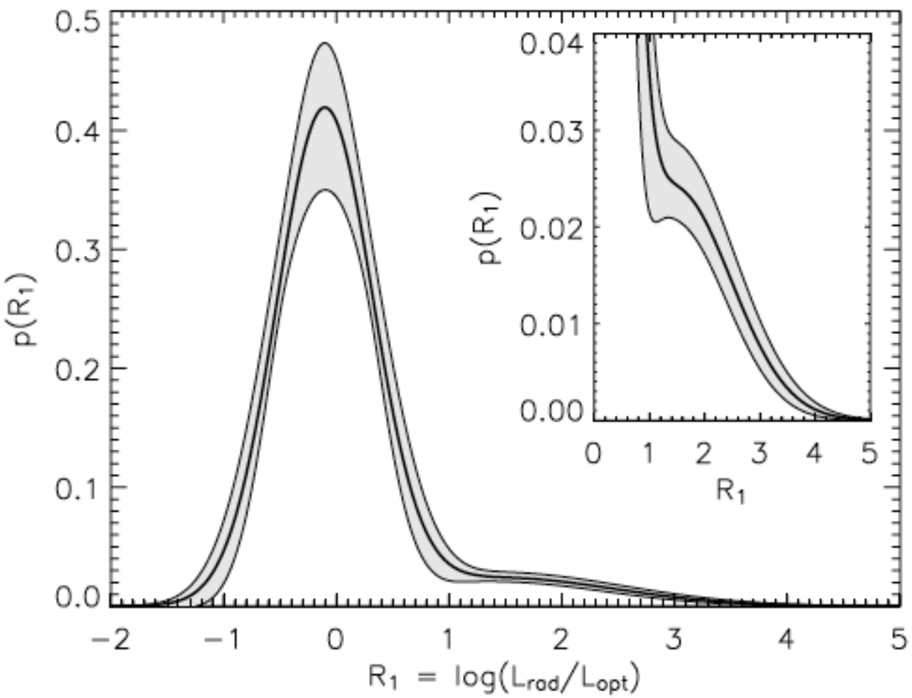
RL/RQ dichotomy

R=f_{6cm} /f_{2500} > 10
~ 10% of AGN are radio loud

➢ RL/RQ dichotomy



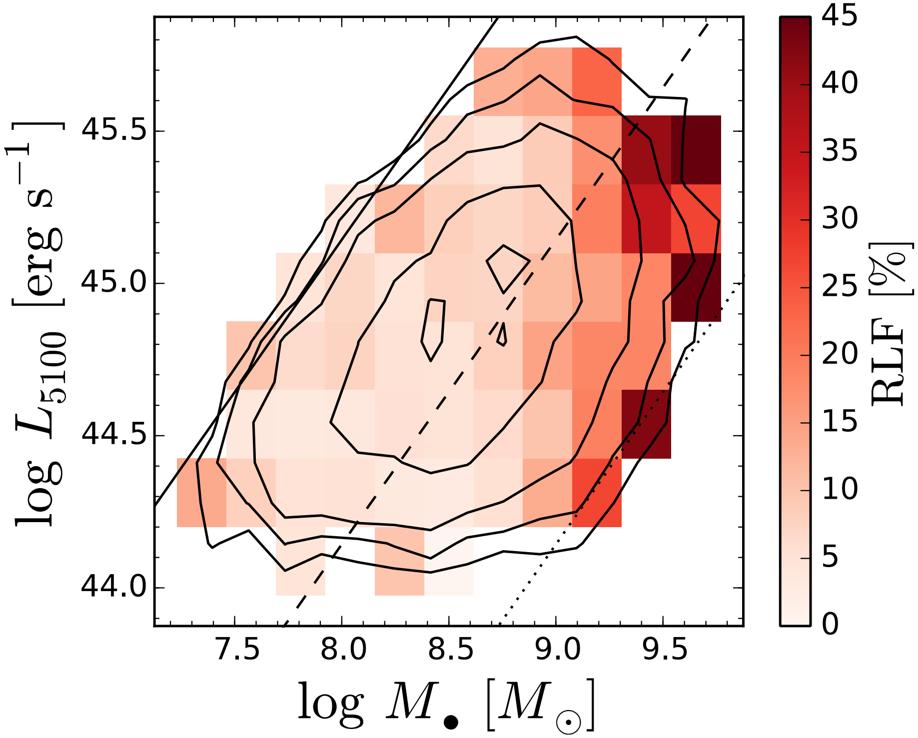
White et al. (2007)

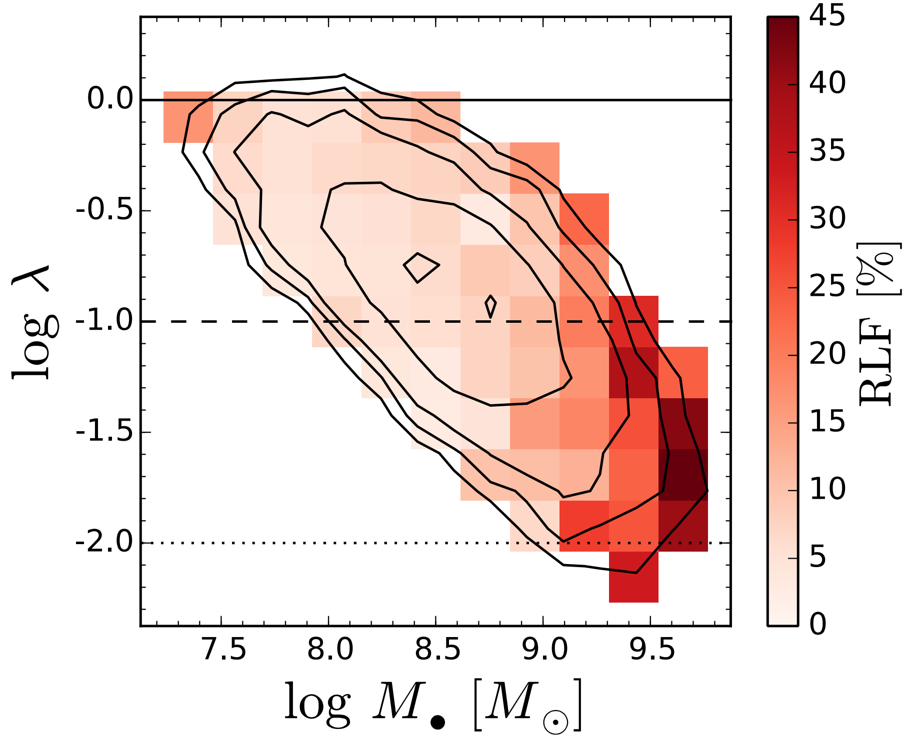


Balokovic et al. (2012)

Parameter dependence of RL fraction

- ➢ Radio loud fraction changes with BH mass and Eddington ratio (e.g. Laor 2000, Kratzer et al. 2015)
- ➢ RL fraction highest at high BH mass and low Eddington ratio

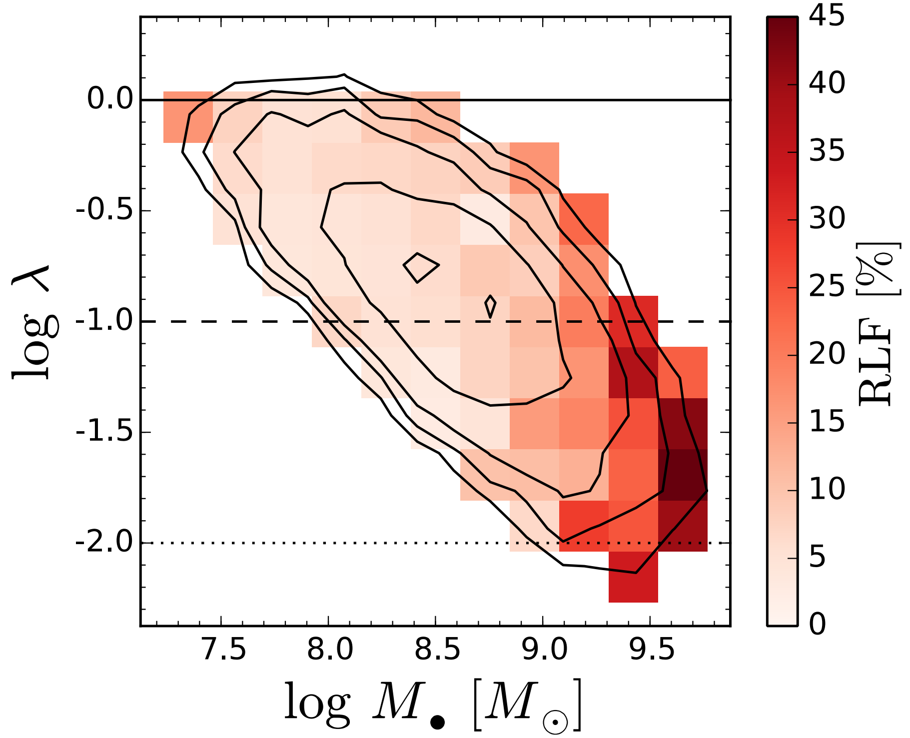




Radio loudness governed by M_{BH} and λ?

- ➢ BH mass and Eddington may play a role but are not sufficient to produce RL quasar
- ➢ Even at high M_{BH}, low λ majority of population is RQ

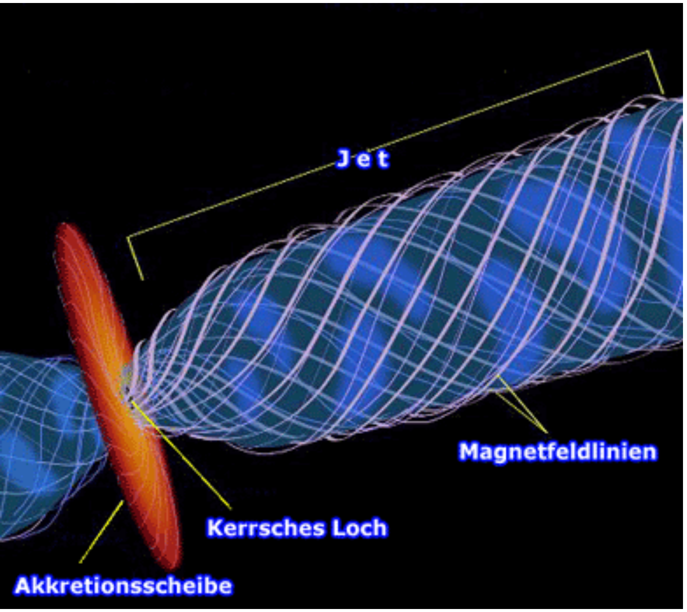
- ➢ What else?
- ⇒ BH spin



The spin paradigm

- ➢ Energy can be extracted from a spinning black hole e.g. via the Blandford-Znajek process (Blandford & Znajek 1977)
- ➢ Magnetic field extracts spin energy

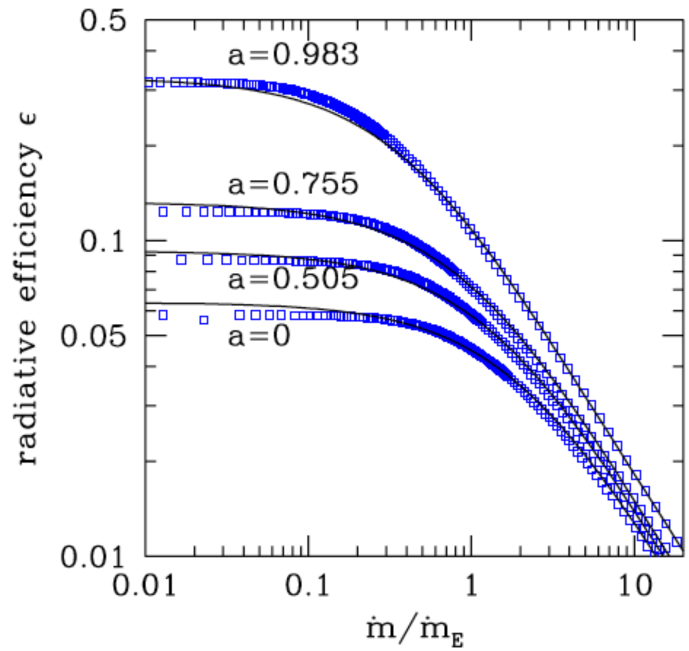
⇒ Collimation of radio jets
=> radio loud AGN



Radiative efficiency as tracer of BH spin

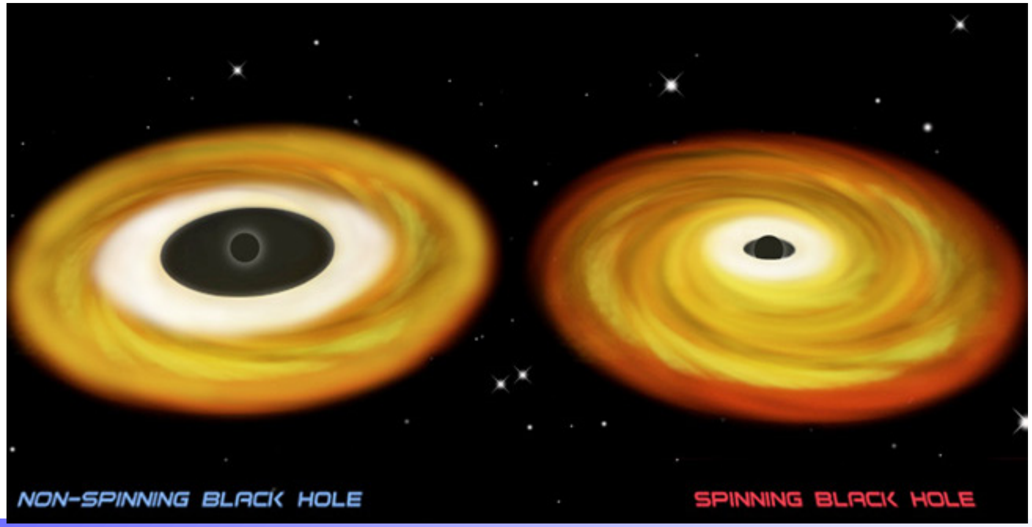
- $L_{bol} = \varepsilon \, \dot{M}_{AD} \, c^2$
- BH spin sets inner edge of accretion disk (ISCO)
- sets radiative efficiency ε

⇒ For thin-disk accretion   ε~0.05-0.42 (for non-spinning – max.-spin BH)



Madau et al. (2014)

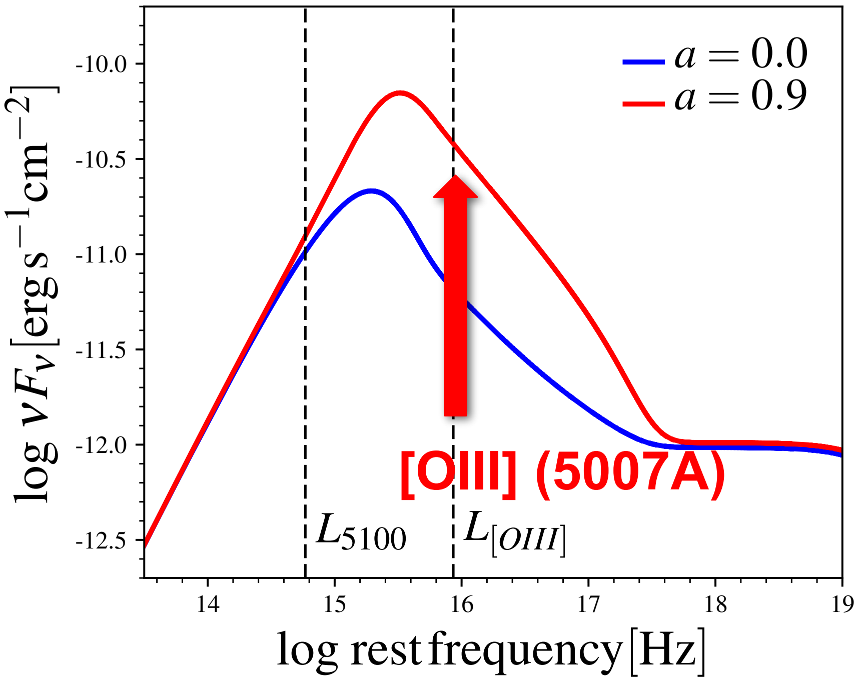
⇒ Focus on luminous, radiatively efficient type-1 QSOs (thin accretion disks)



SED for RL and RQ QSOs

- At fixed optical luminosity, difference in SED in EUV regime expected as function of BH spin
- EUV cannot be directly probed

⇒ Use [OIII] as average tracer of L_{bol} via probing the peak of SED in UV regime



Sample of RL and RQ quasars

➢ Focus on luminous type-1 QSOs from SDSS

Sample:

➢ SDSS DR7 QSO catalog, uniform target within FIRST footprint

➢ $i<18.9$ (to match optical depth and FIRST depth for RL/RQ classification)

➢ $0.3<z<0.84$

➢ measured BH mass from Hbeta and measured [OIII] luminosity

➢ Accretion rates from Wu et al. (2013)

➢ RL: 757 RQ: 7187

⇒ Control RL and RQ sample for BH mass, Luminosity, $\dot{M}_{AD}$

(1) match on grid (2) match individual objects

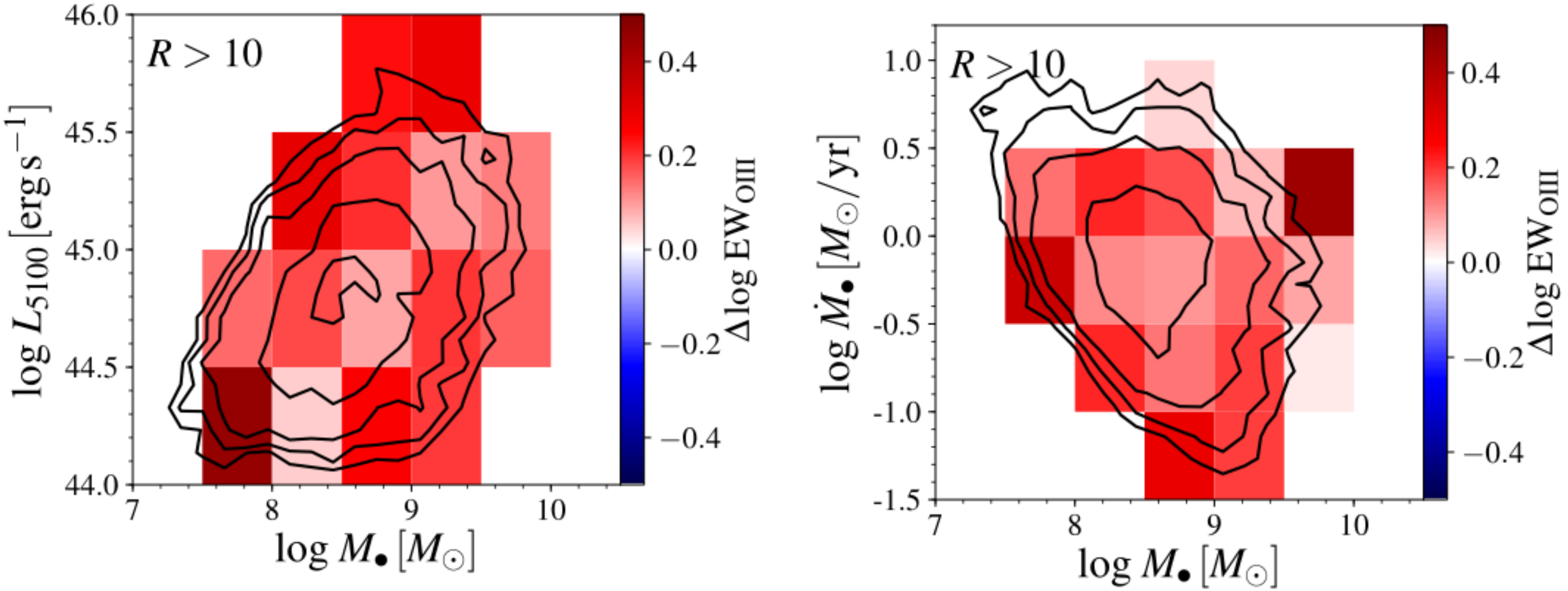
⇒ Do RL and RQ have same average radiative efficiency?

$L_{bol}=\varepsilon \dot{M}_{AD} c^2$

Enhanced L_{OIII} in RL quasars

Difference in L_{OIII} between RL and RQ QSOs in grid on M_{BH},L_{5100} or M_{BH}, $\dot{M}_{AD}$

⇒ Radio loud QSOs have enhanced L_{OIII}



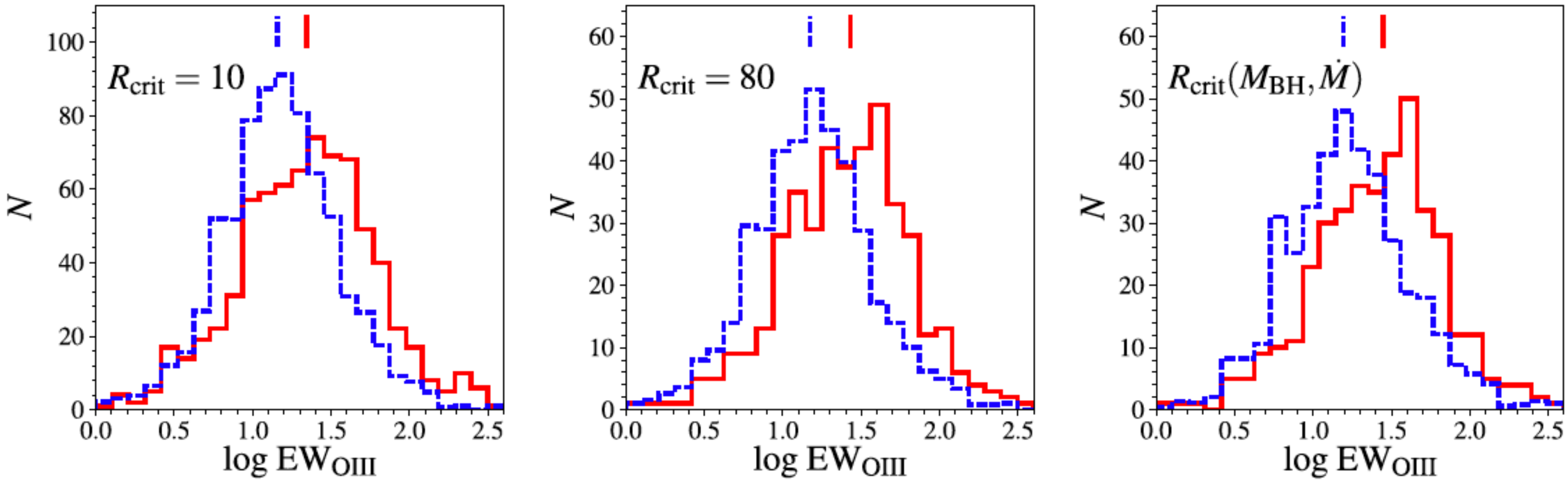
Schulze et al. (in prep.)

Enhanced L_{OIII} in RL quasars

- ➢ Compare RL QSOs and matched RQ sample, in z, M_{BH} and L_{5100}
- ➢ Mean offset in log L_{OIII} distributions of 0.18 dex => factor 1.5

⇒ KS-test: D=0.188 p=5.204e-20

⇒ Result independent of definition of RL

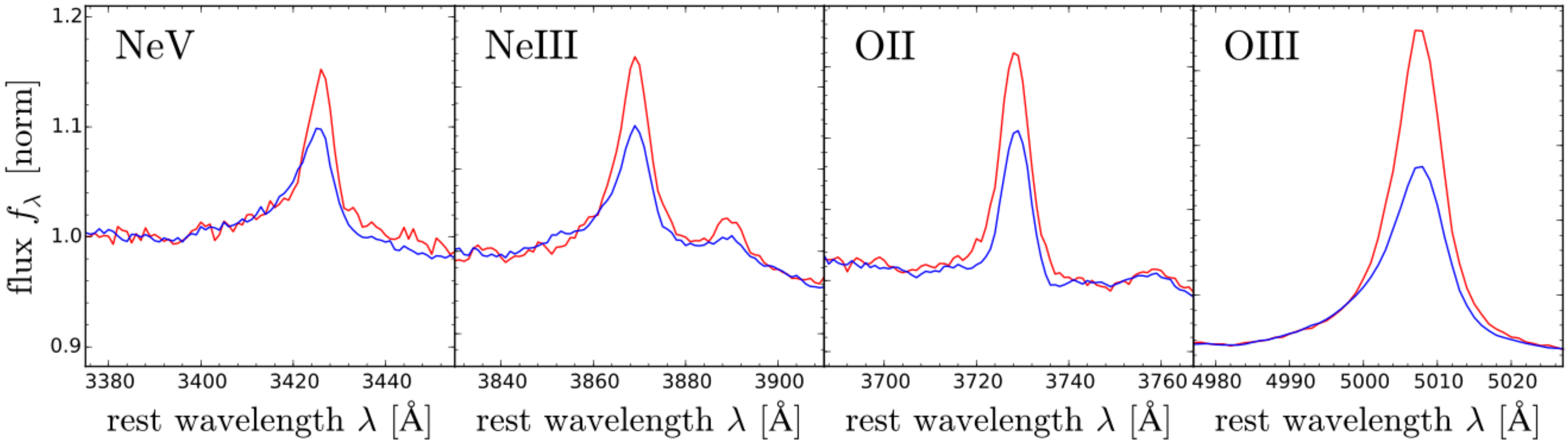


Narrow emission lines in spectral stack

Stack of RL and RQ matched QSO samples

OIII profile:
⇒ enhancement due to core emission
⇒ trend is not driven by outflows/shocks

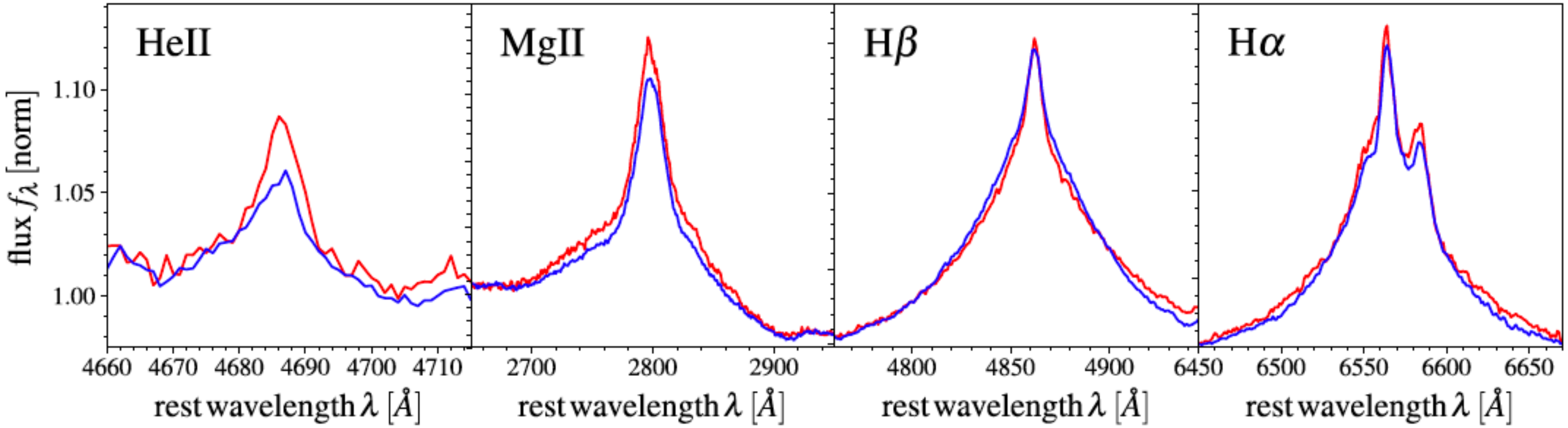
⇒ same enhancement present in all high excitation narrow lines



Broad emission lines in spectral stack

⇒ Low ionization broad lines of Balmer lines and MgII show no strong difference between RL and RQ stack

⇒ High ionization broad line of HeII **does** show enhancement in RL stack, similar to narrow lines



RL quasars have higher BH spin

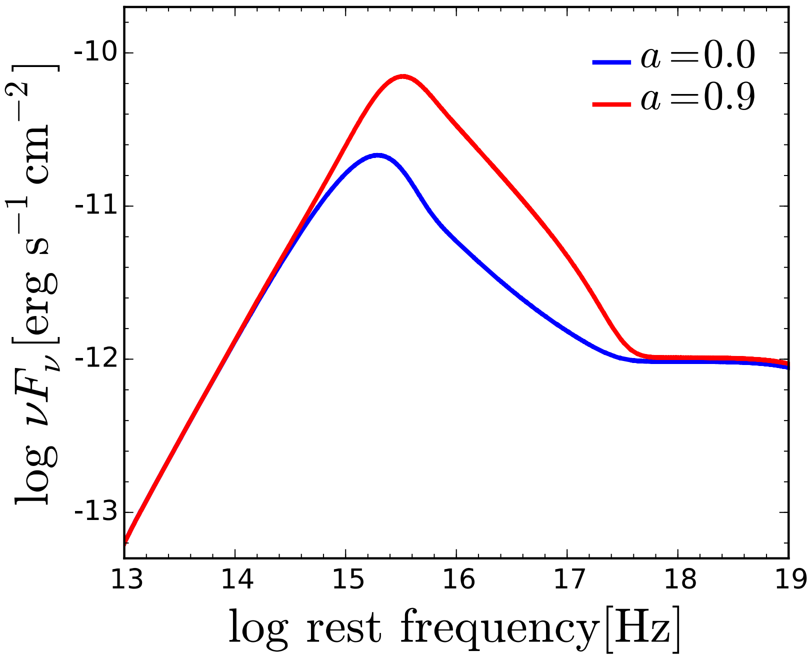
⇒ RL quasars have higher L_{bol} at a given $\dot{M}_{AD}$

$L_{bol}=\varepsilon \dot{M}_{AD} c^2$

⇒ have average radiative efficiency factor 1.5 higher than RQ quasars

⇒ RL quasars have higher average BH spin

⇒ different BH spin distributions



assume:

RQ: ε=0.1 => a=0.67

RL: ε=0.15 => a=0.89

Schulze et al. 2017, ApJ, 849, 4

Thank you!