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Jet powering mechanism in radio quasars from the LOFAR Two-metre Sky Survey

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Supervisors: Prof. Philip Best, Dr. Ken Duncan, Prof. Huub Röttgering

07/07/25, NAM 2025

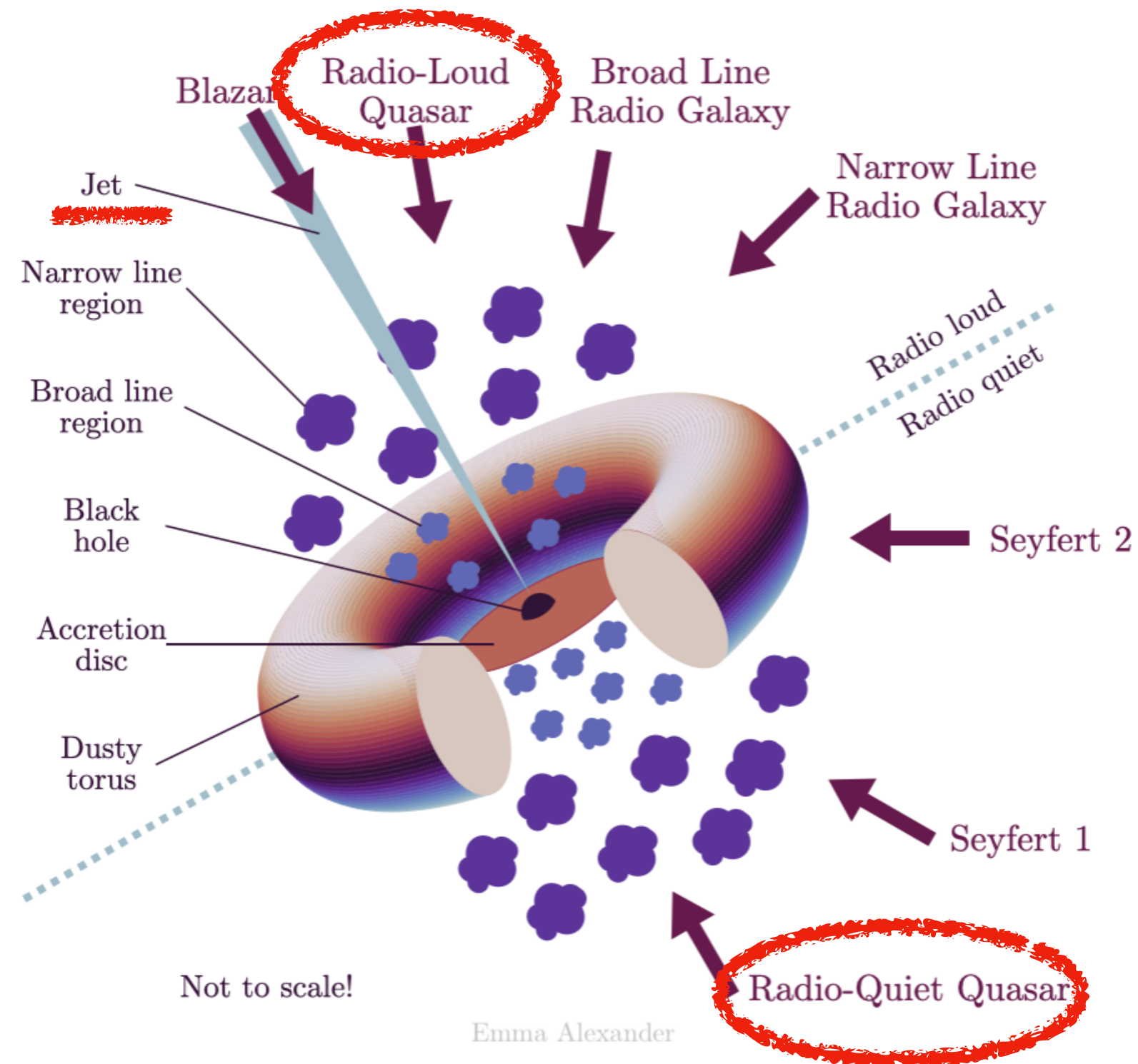
Background

Radio quasars in the era of deep radio surveys

- Radio quasar as we know it:

...But is this the real case?

- separated into RL/RQ (based on radio detection)
- linked with jet presence

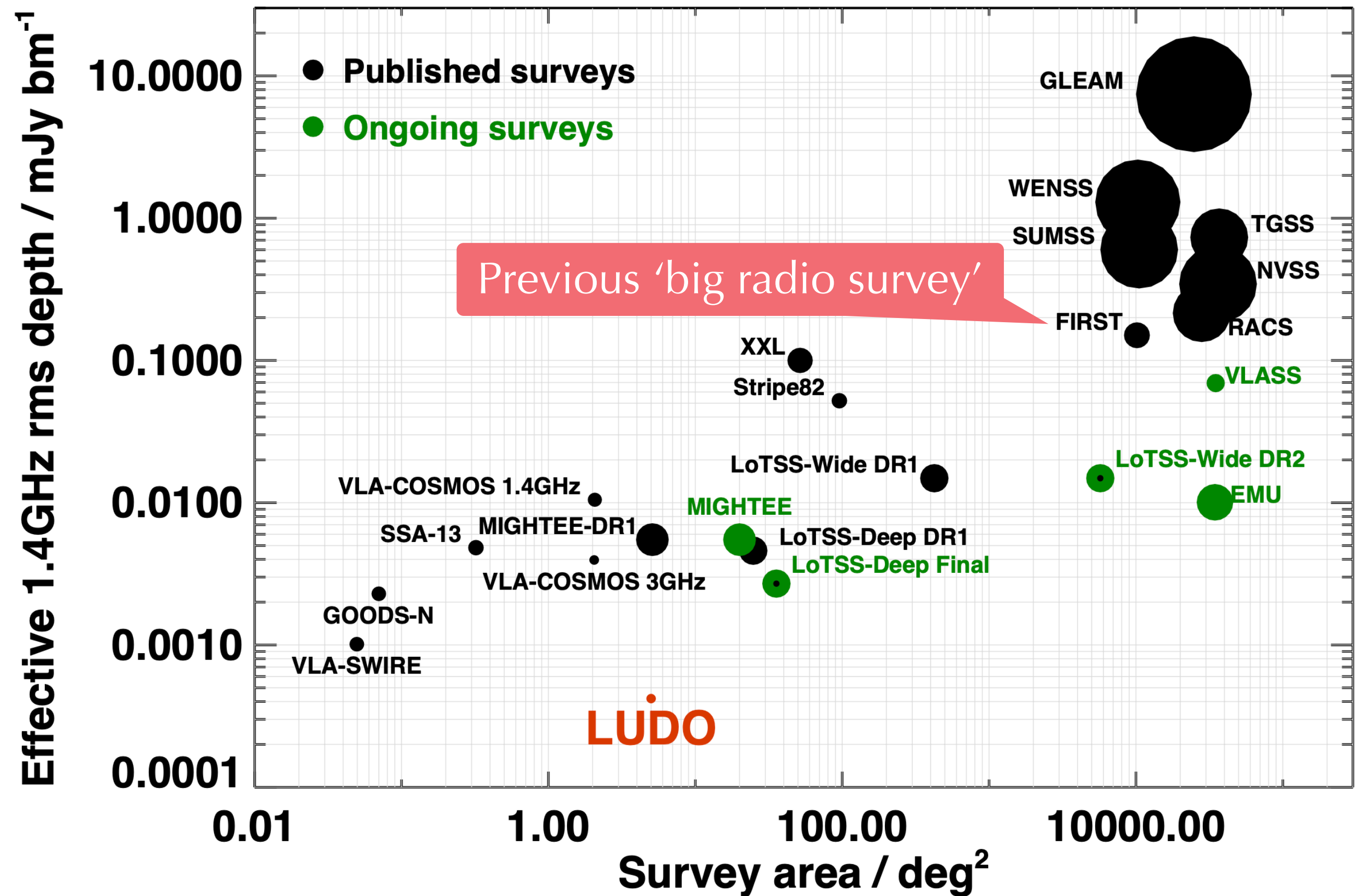
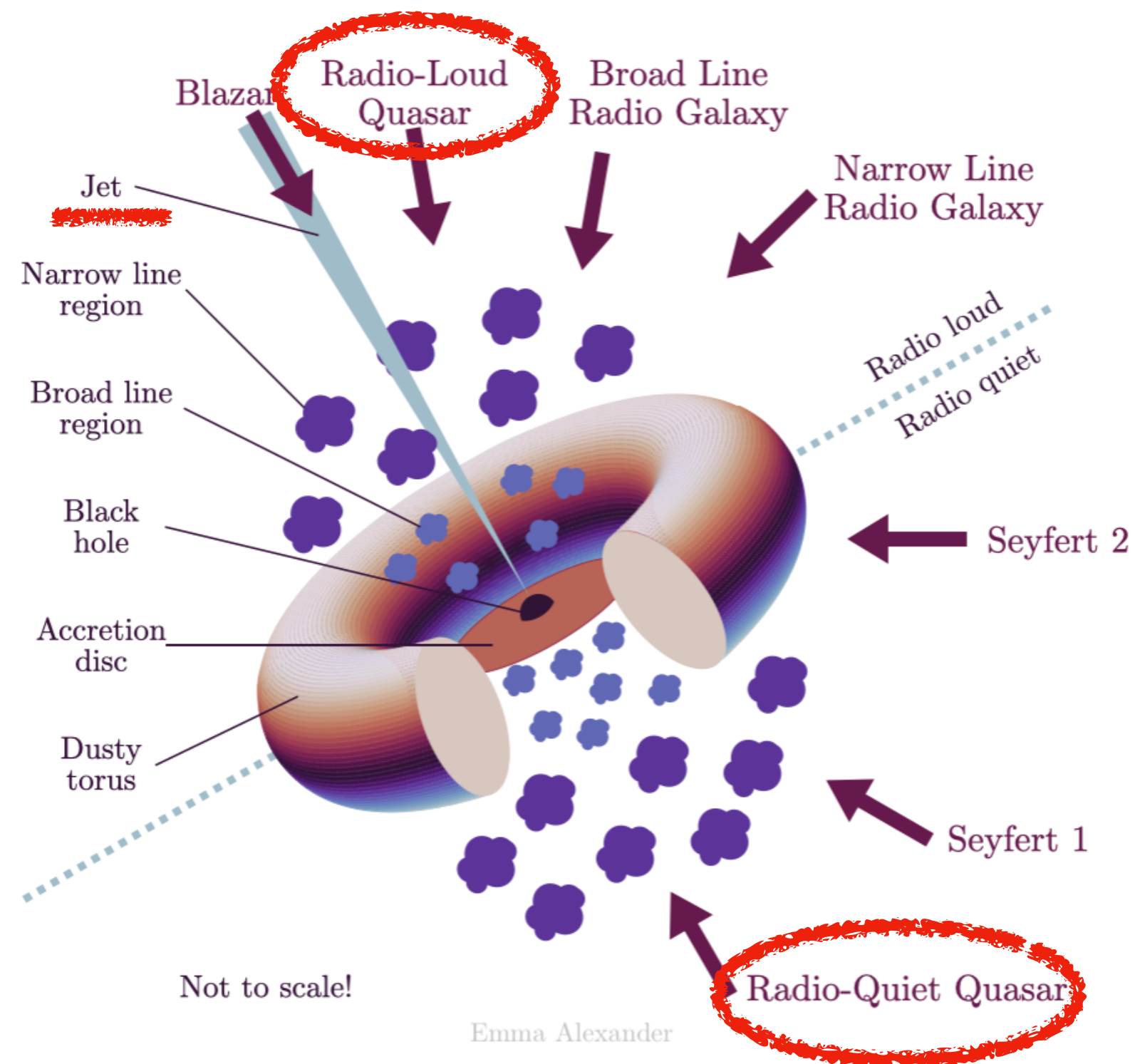


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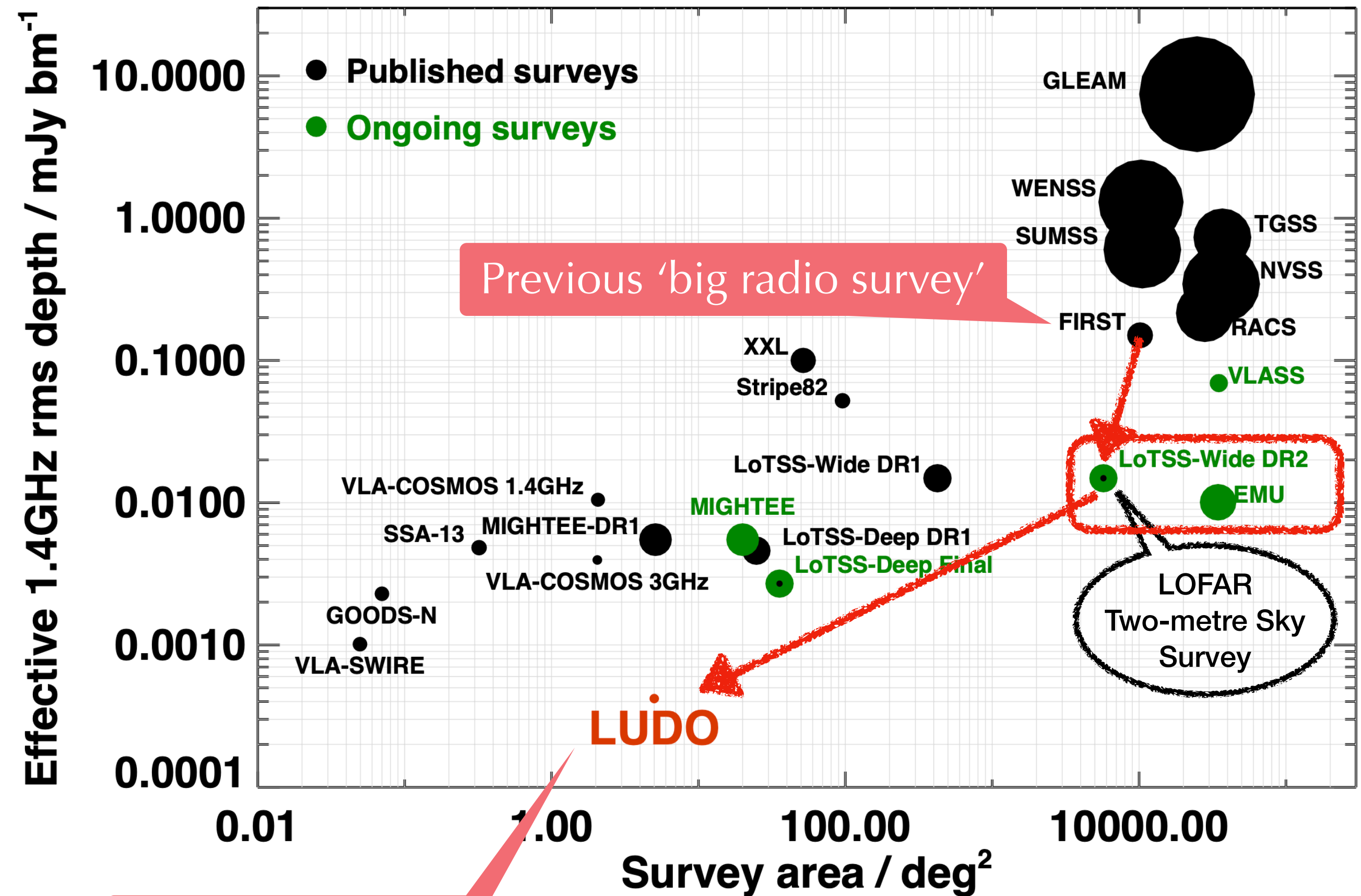
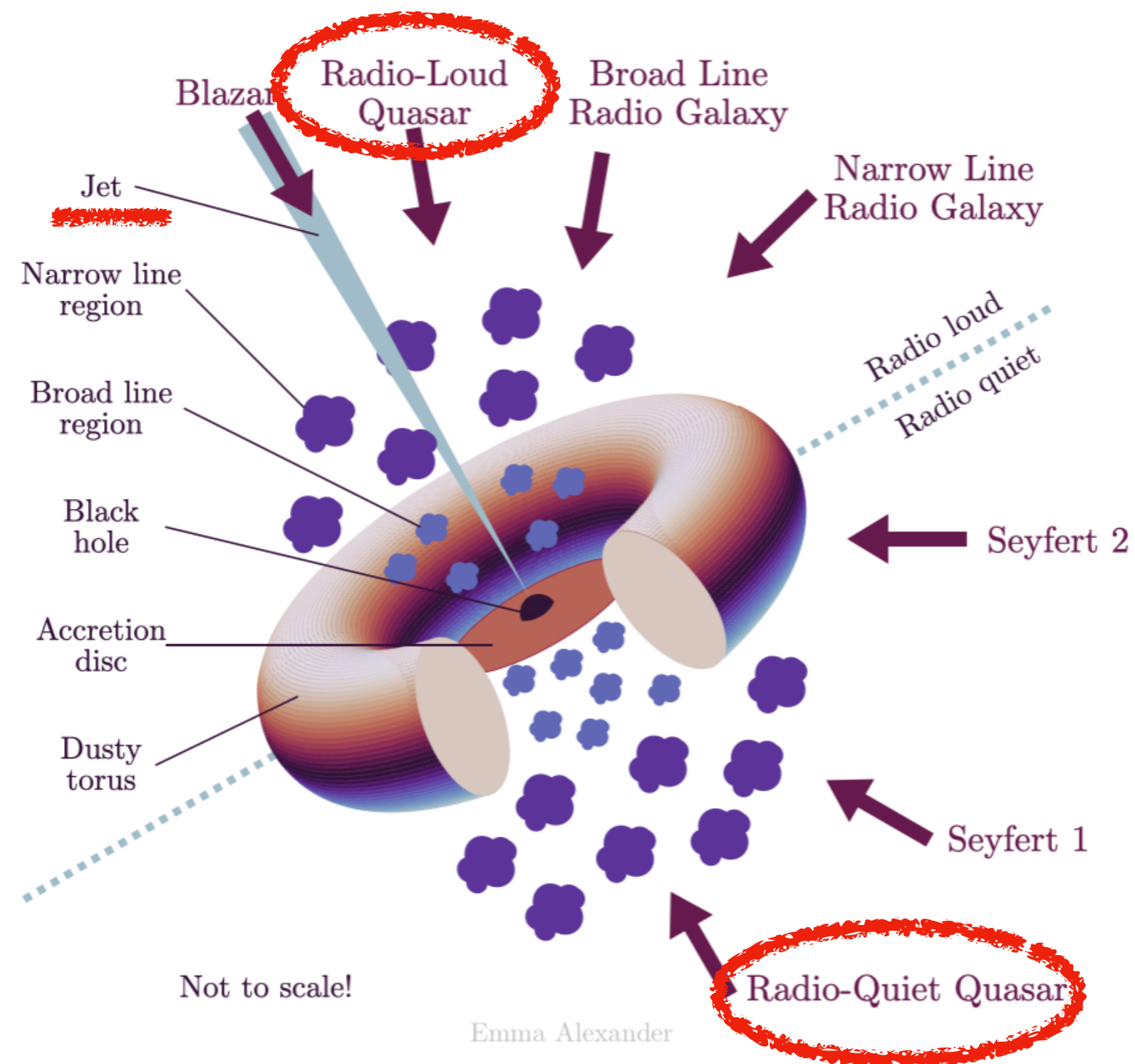
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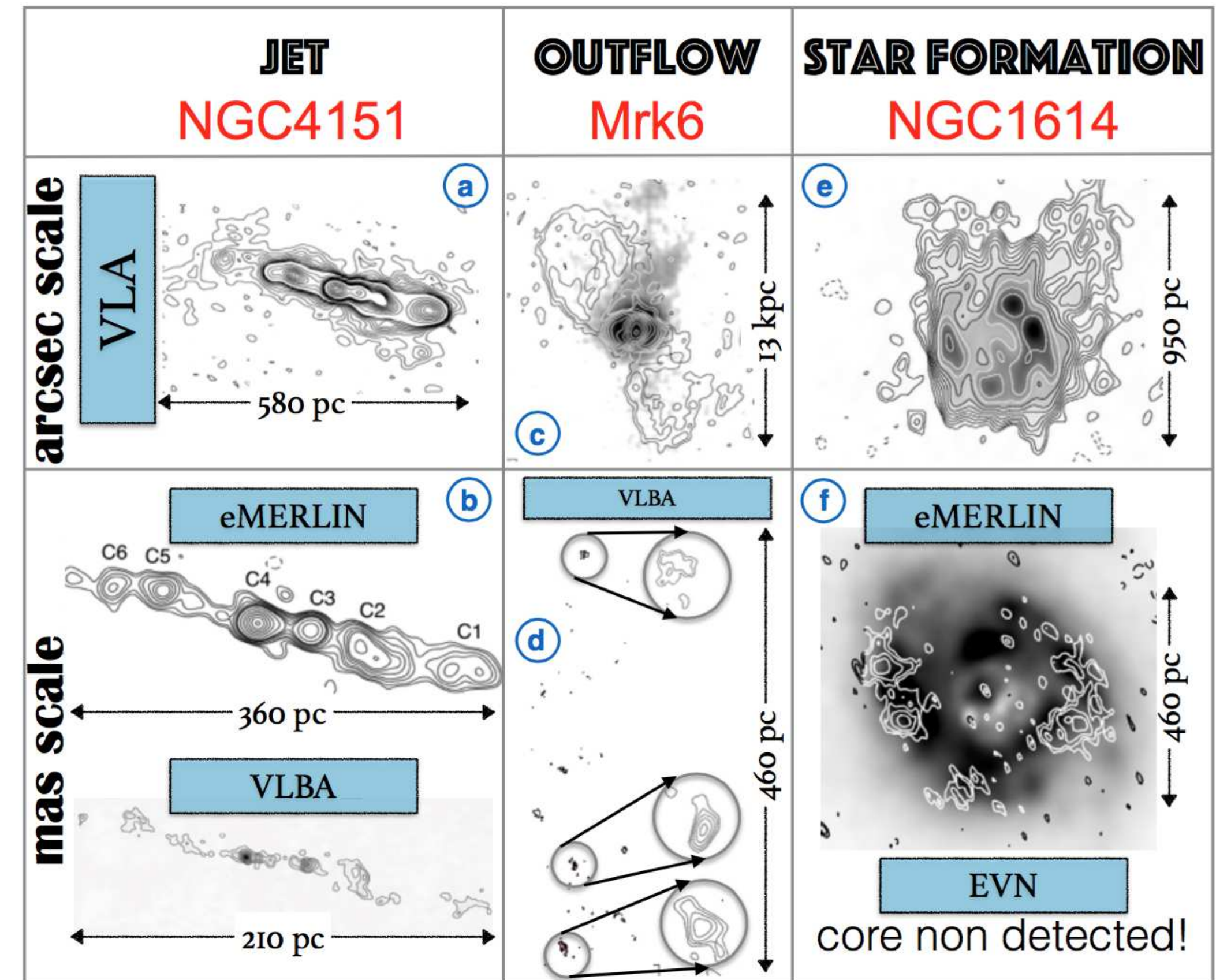
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Radio quasars in the era of deep radio surveys

- Next-gen radio surveys probes well into the 'radio-quiet' regime:
 - ➔ Jets in RQ AGNs: VLBI observation challenges RL/RQ dichotomy

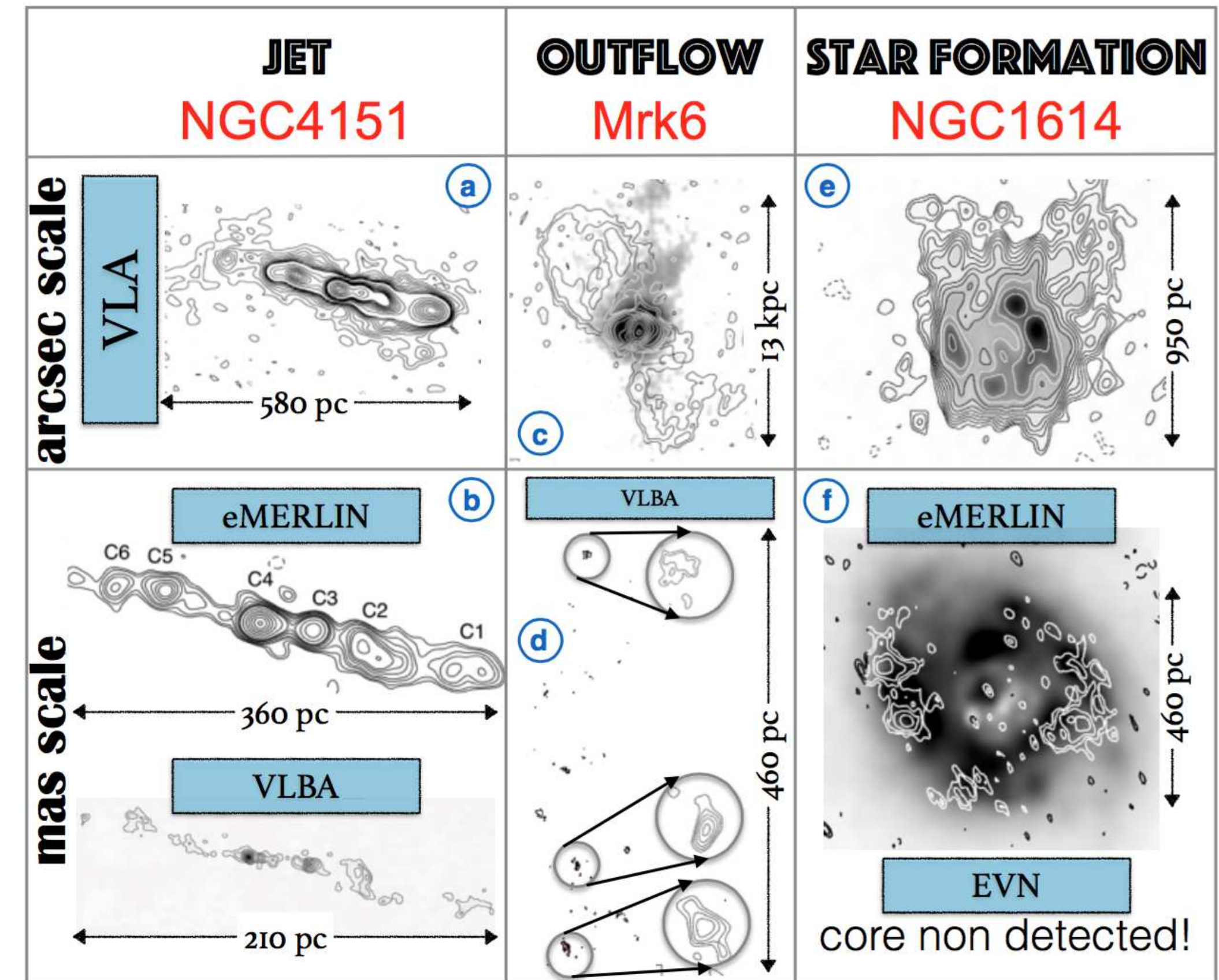


Credit: Panessa+19

Background

Radio quasars in the era of deep radio surveys

- Next-gen radio surveys probes well into the 'radio-quiet' regime:
 - ➔ Jets in RQ AGNs: VLBI observation challenges RL/RQ dichotomy
 - *What powers the radio emission in RQ AGNs?*
 - *How to distinguish between the host galaxy star formation (SF) and weak AGN activities (jet/outflow)?*
- ★ What causes the powering efficiency of jets to vary across a wide range?



Credit: Panessa+19

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Radio quasars in the era of deep radio surveys

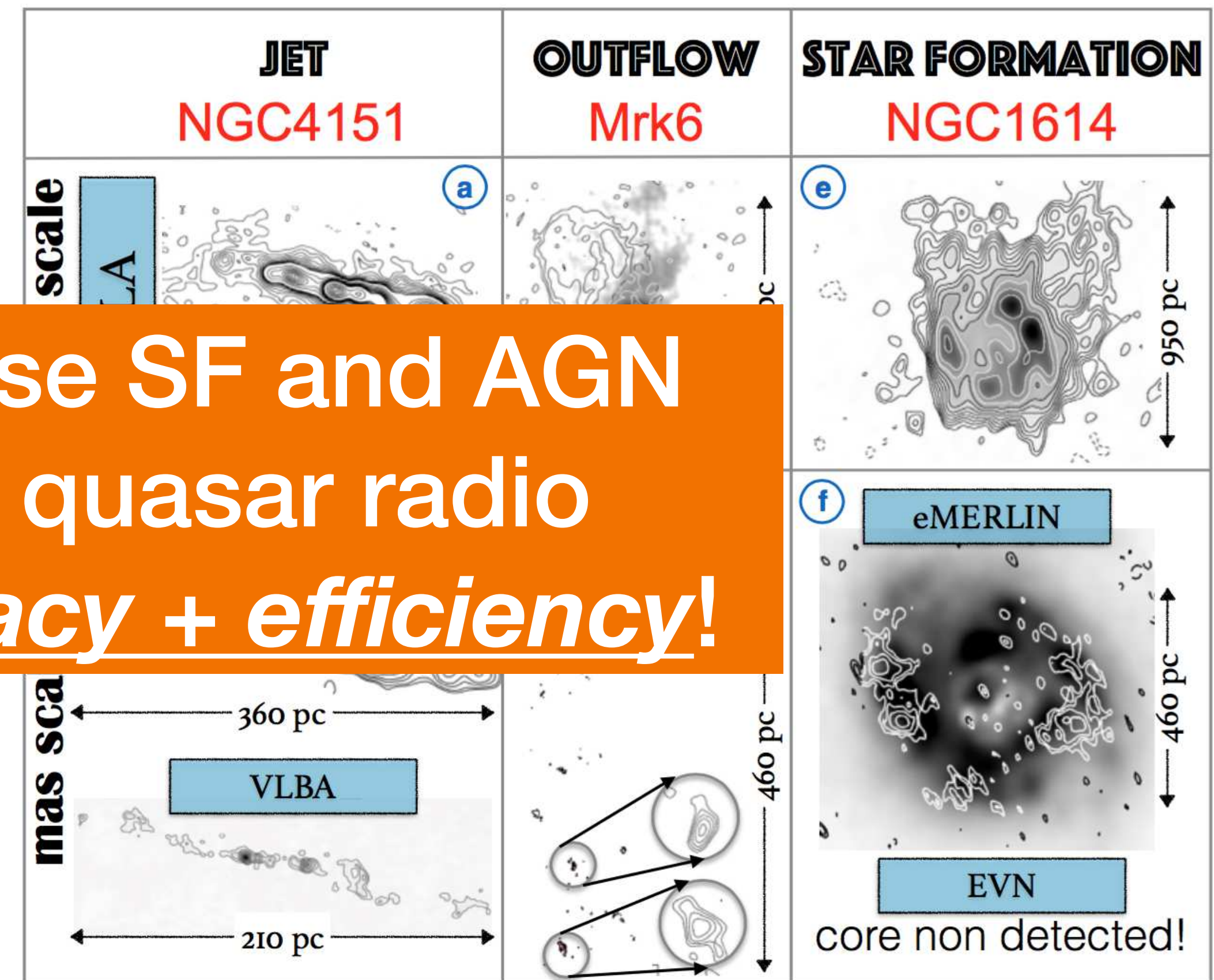
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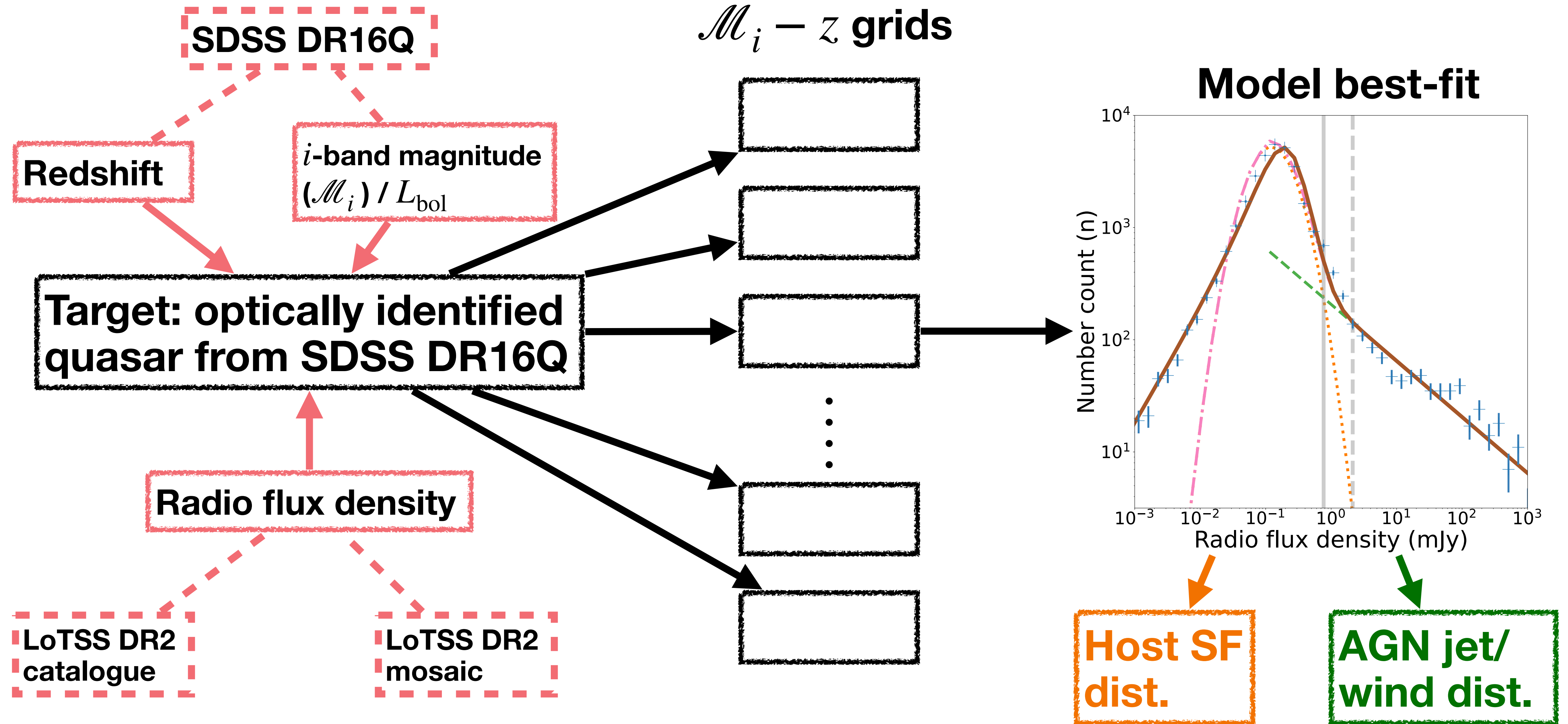
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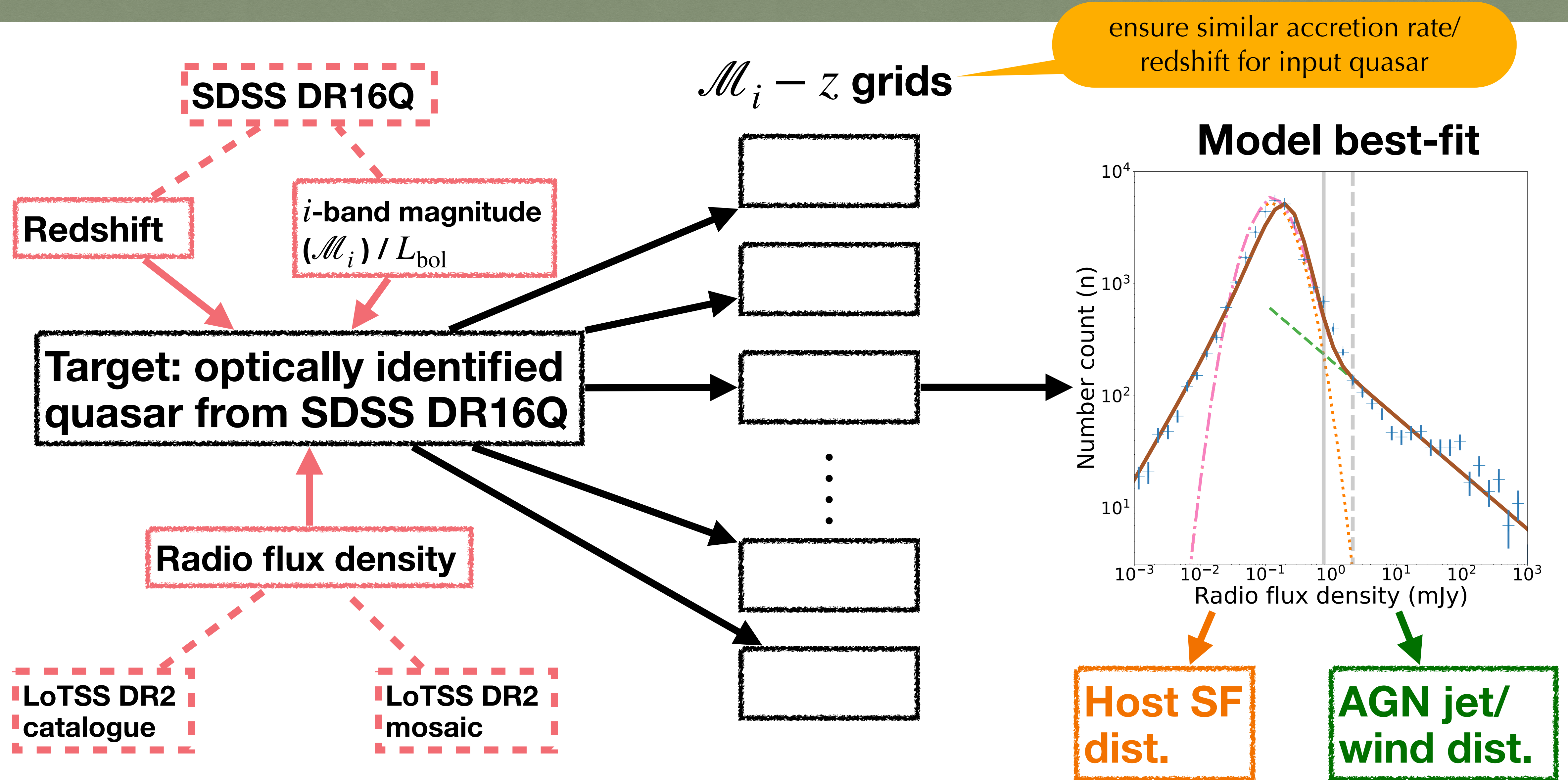
Two-component Bayesian model

Separating SF and AGN in radio flux density distribution



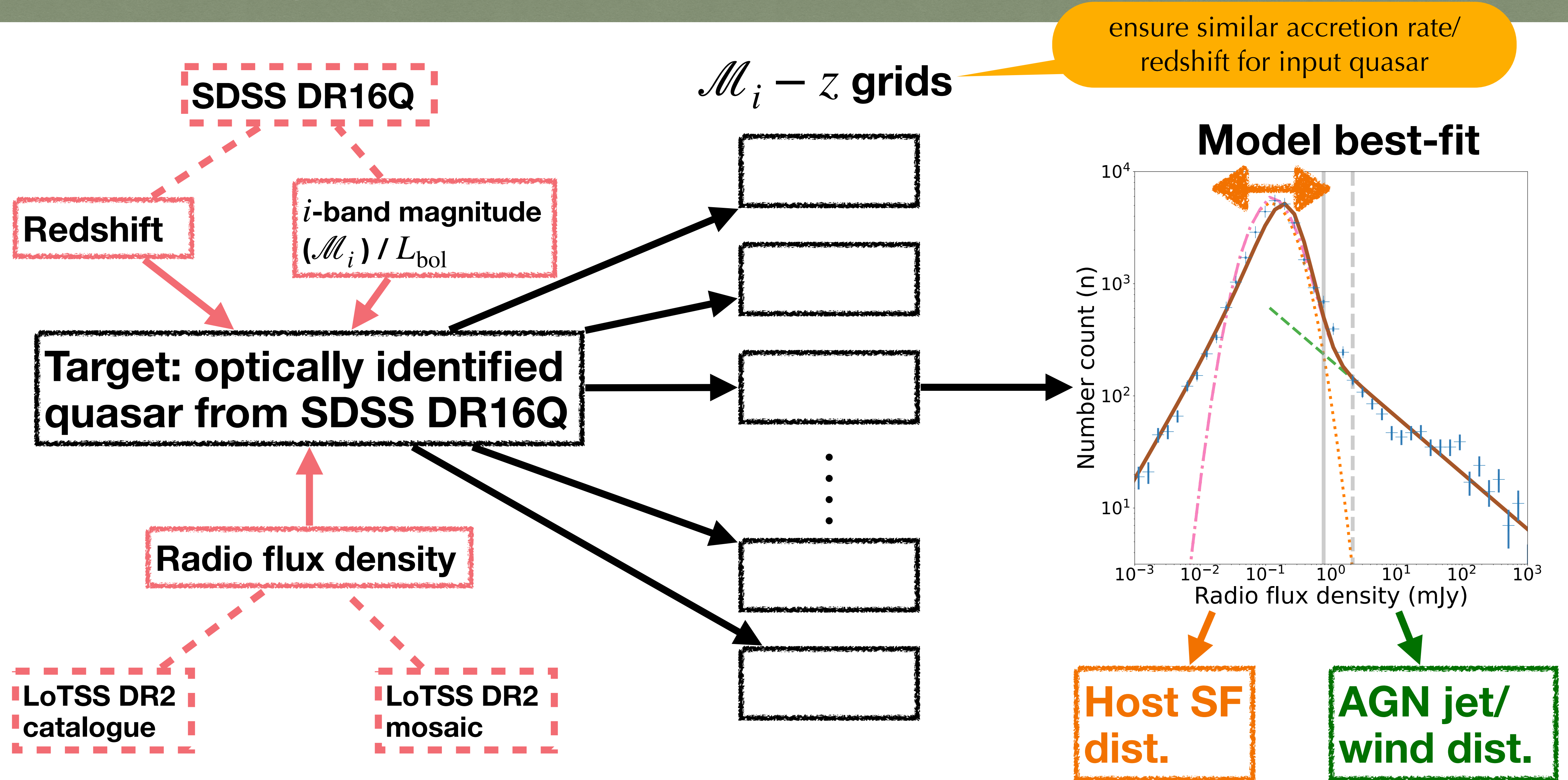
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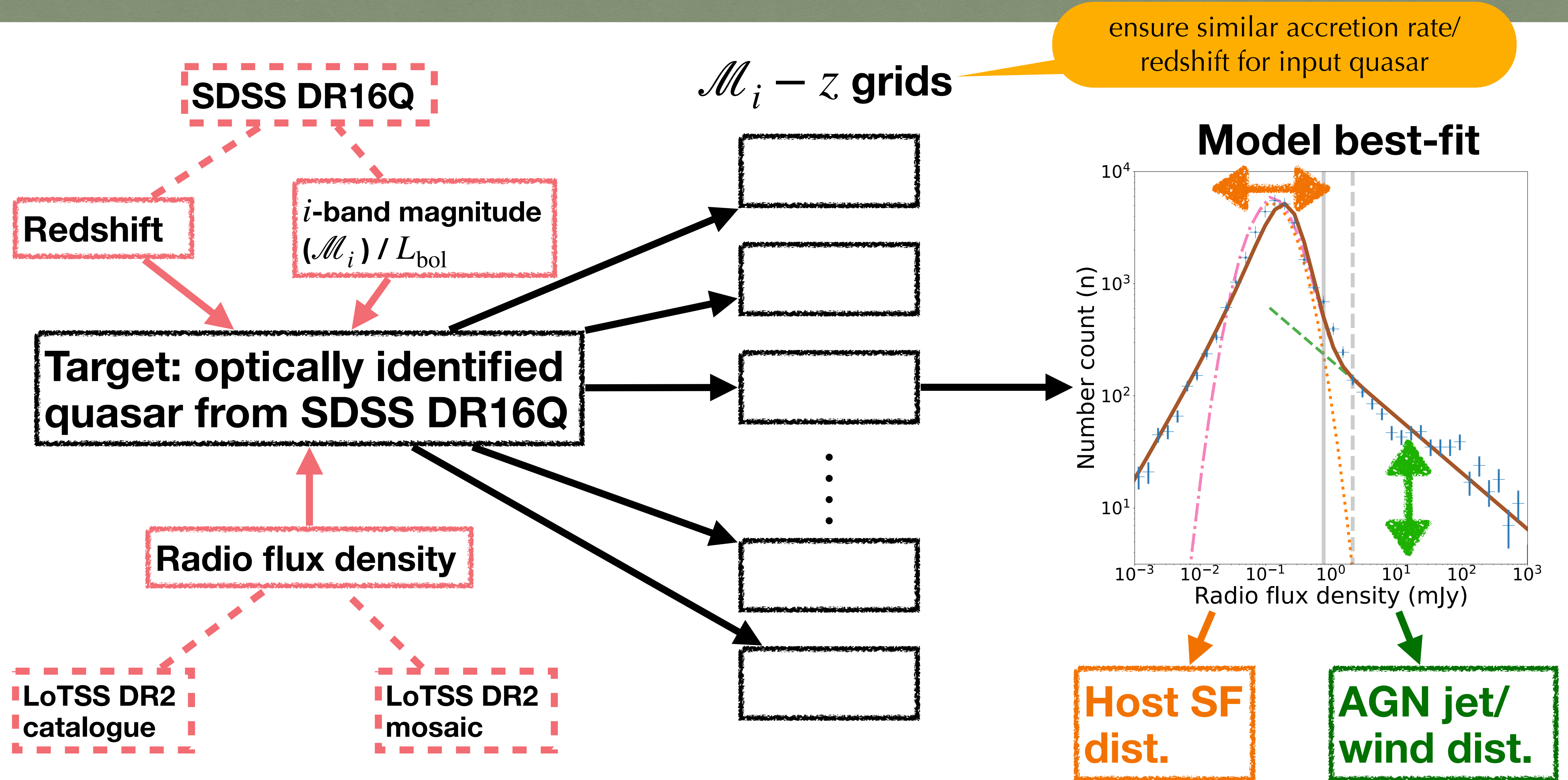
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Two-component Bayesian model

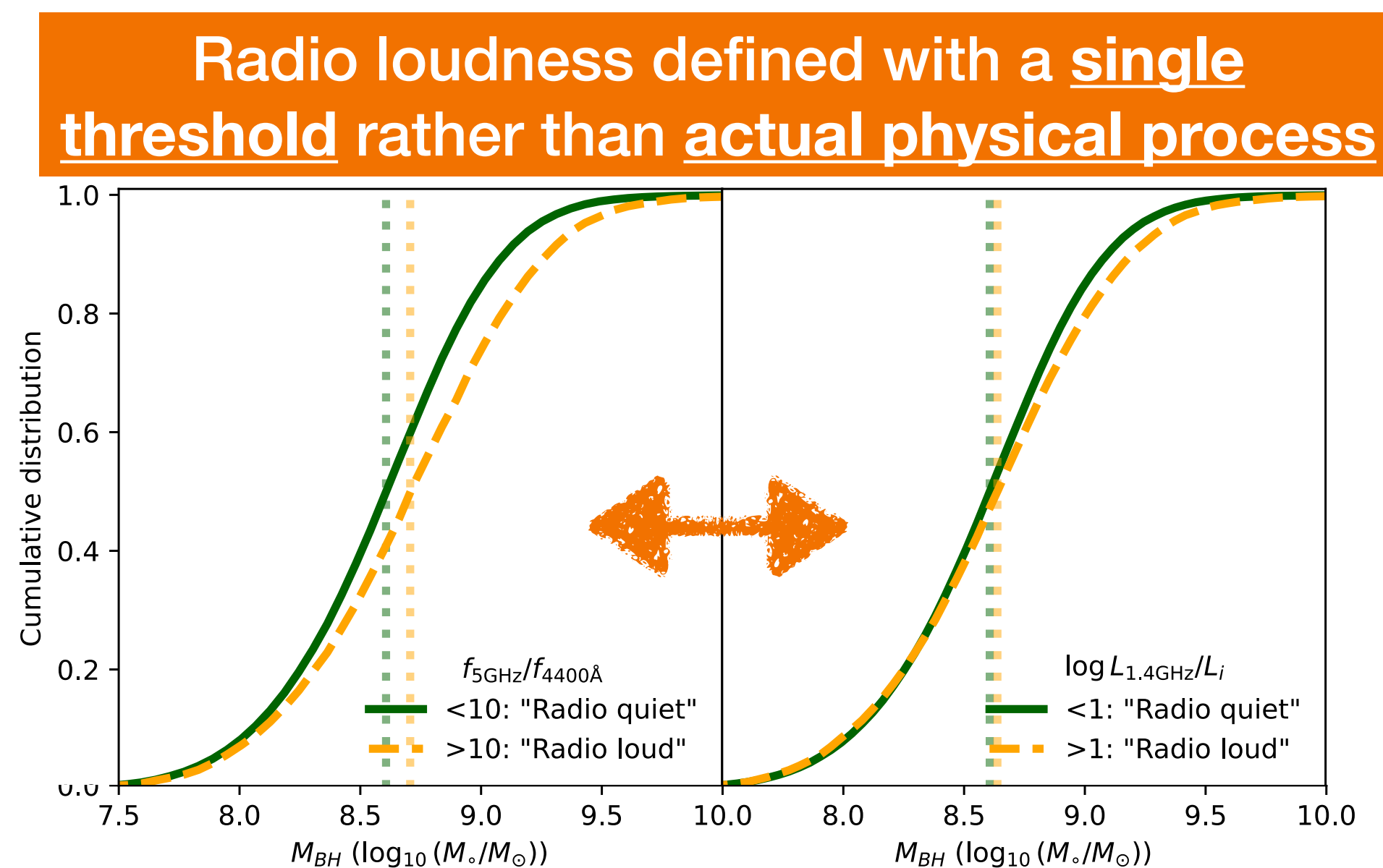
Separating SF and AGN in radio flux density distribution



Link to jet power: BH mass

Is 'radio-loudness' a good definition?

- **NO** - radio power evolves with bolometric luminosity and redshift!
- The two-component model enables classification by **physical processes** on survey datasets



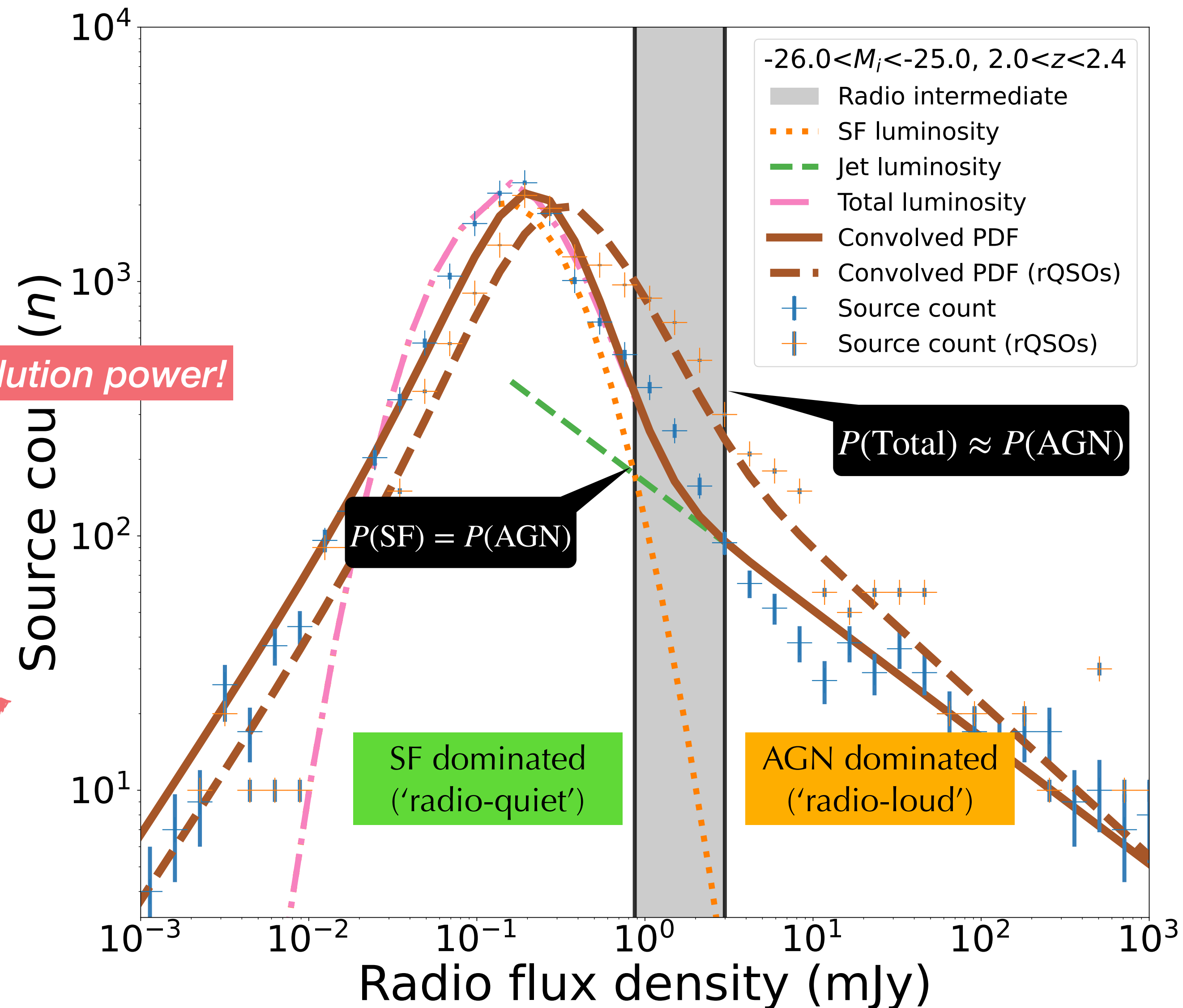
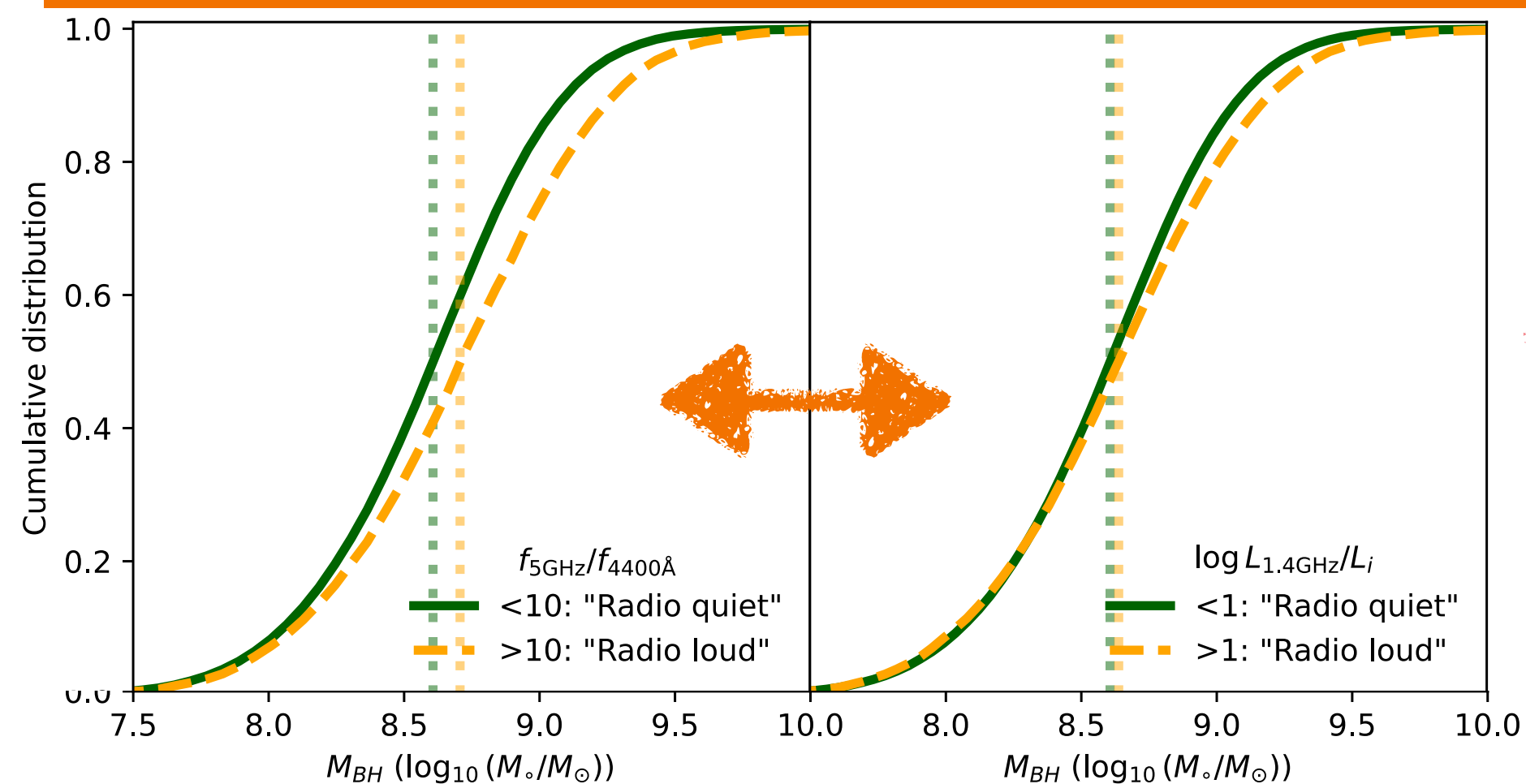
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Available with less depth / resolution power!

Radio loudness defined with a single threshold rather than actual physical process



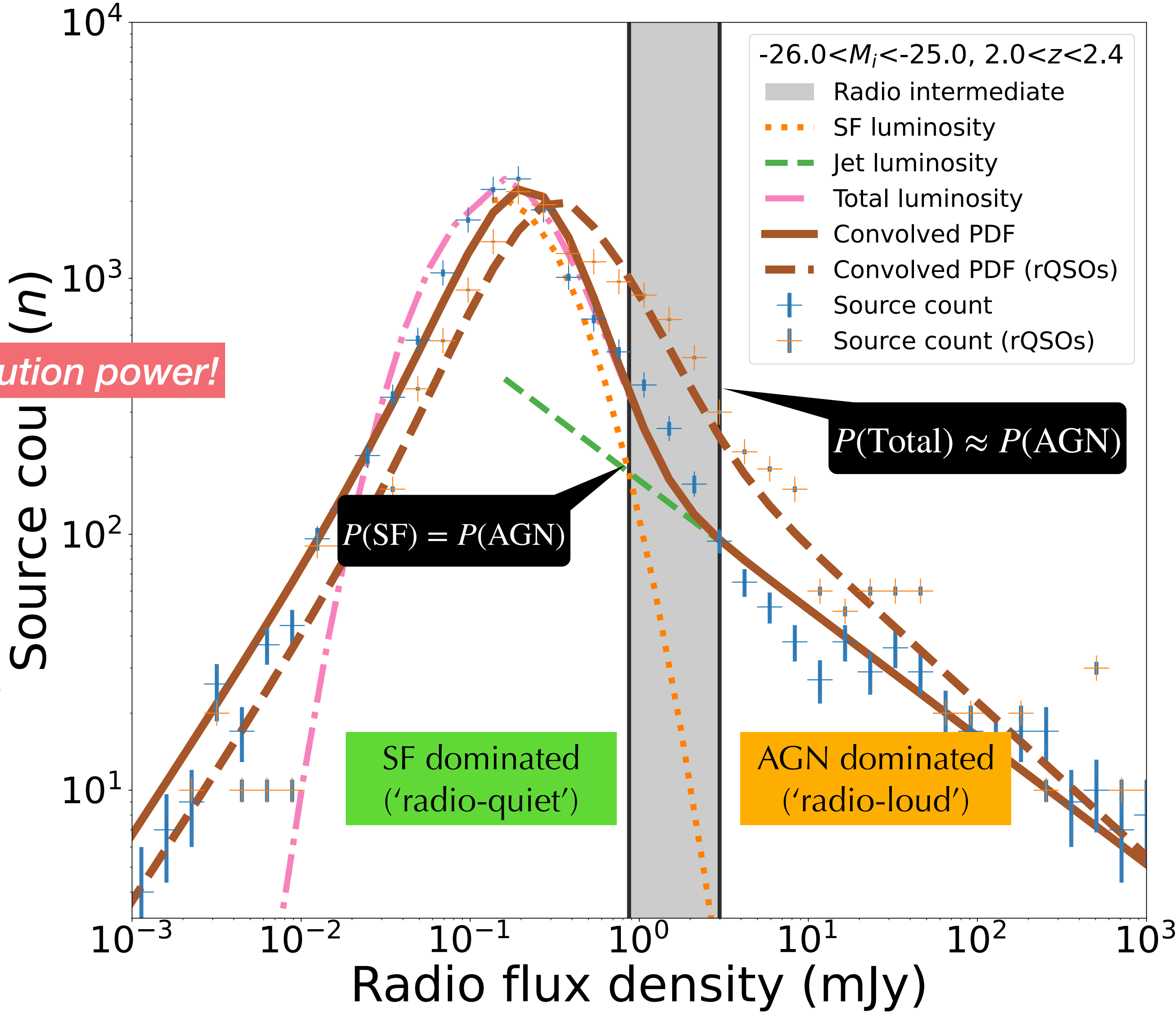
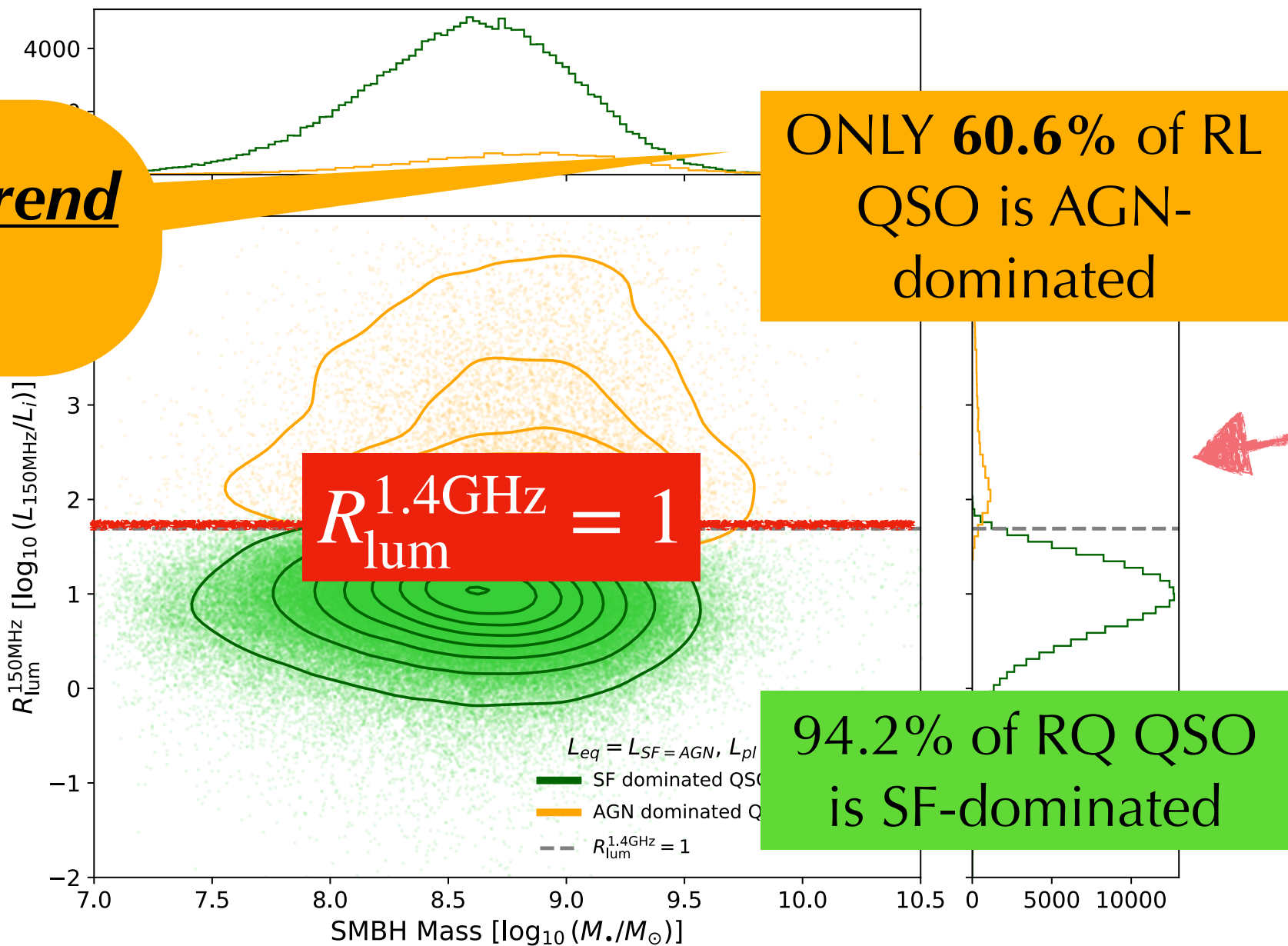
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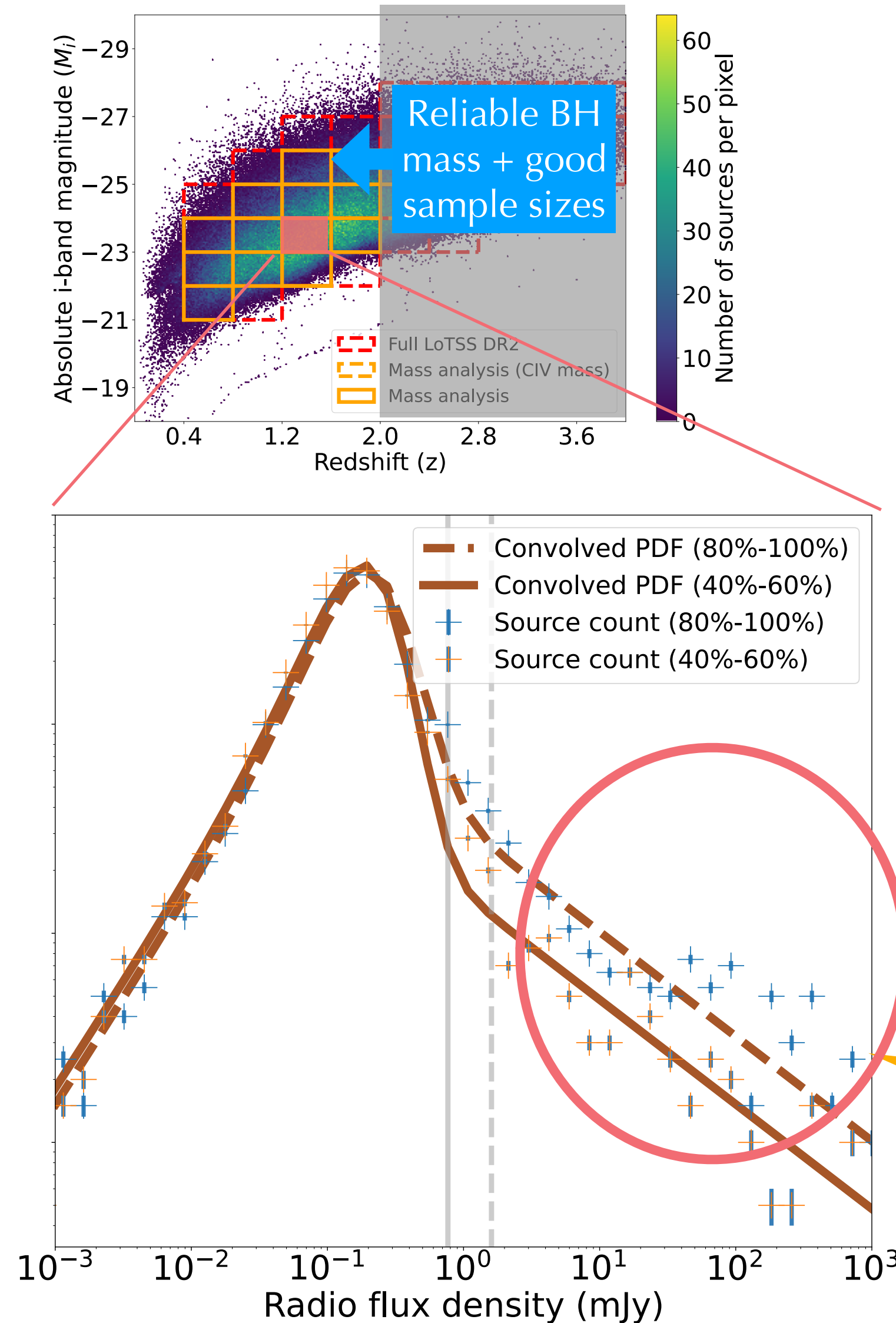
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Wiped out the trend in RL QSOs



Link to jet power: BH mass

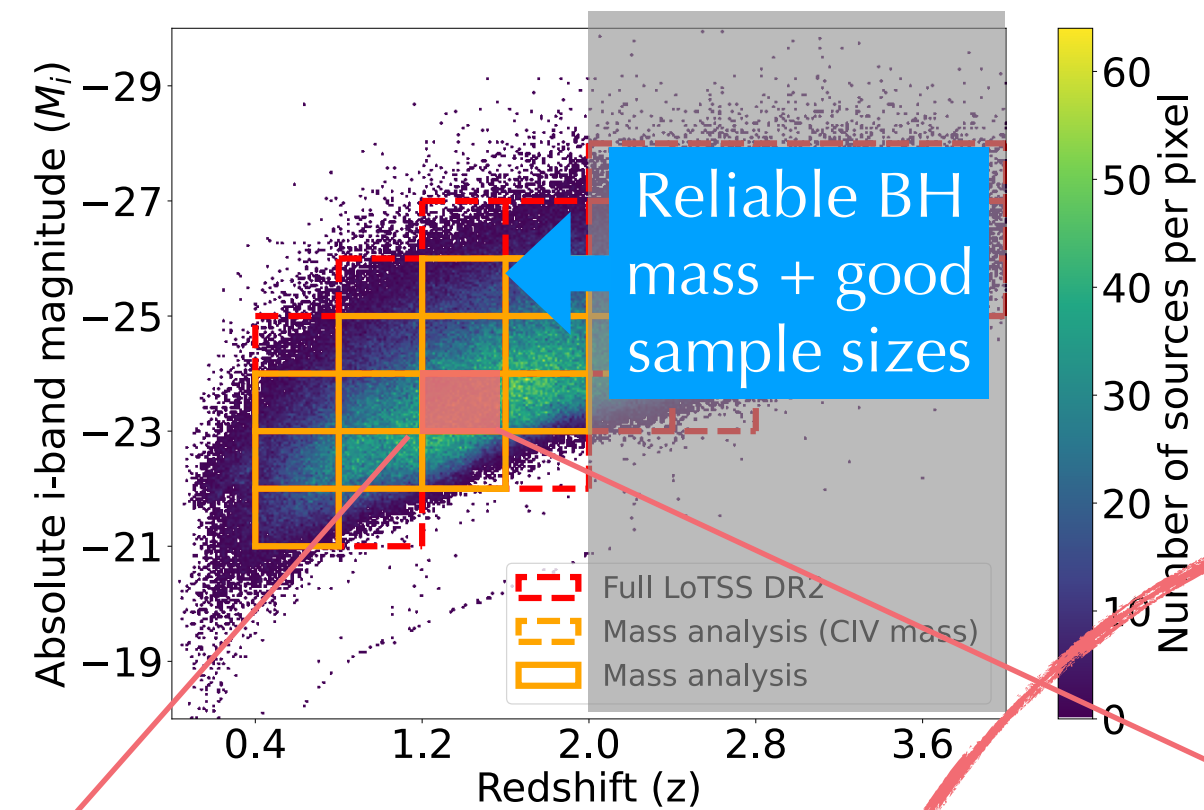
Direct evidence from model (Yue+25)



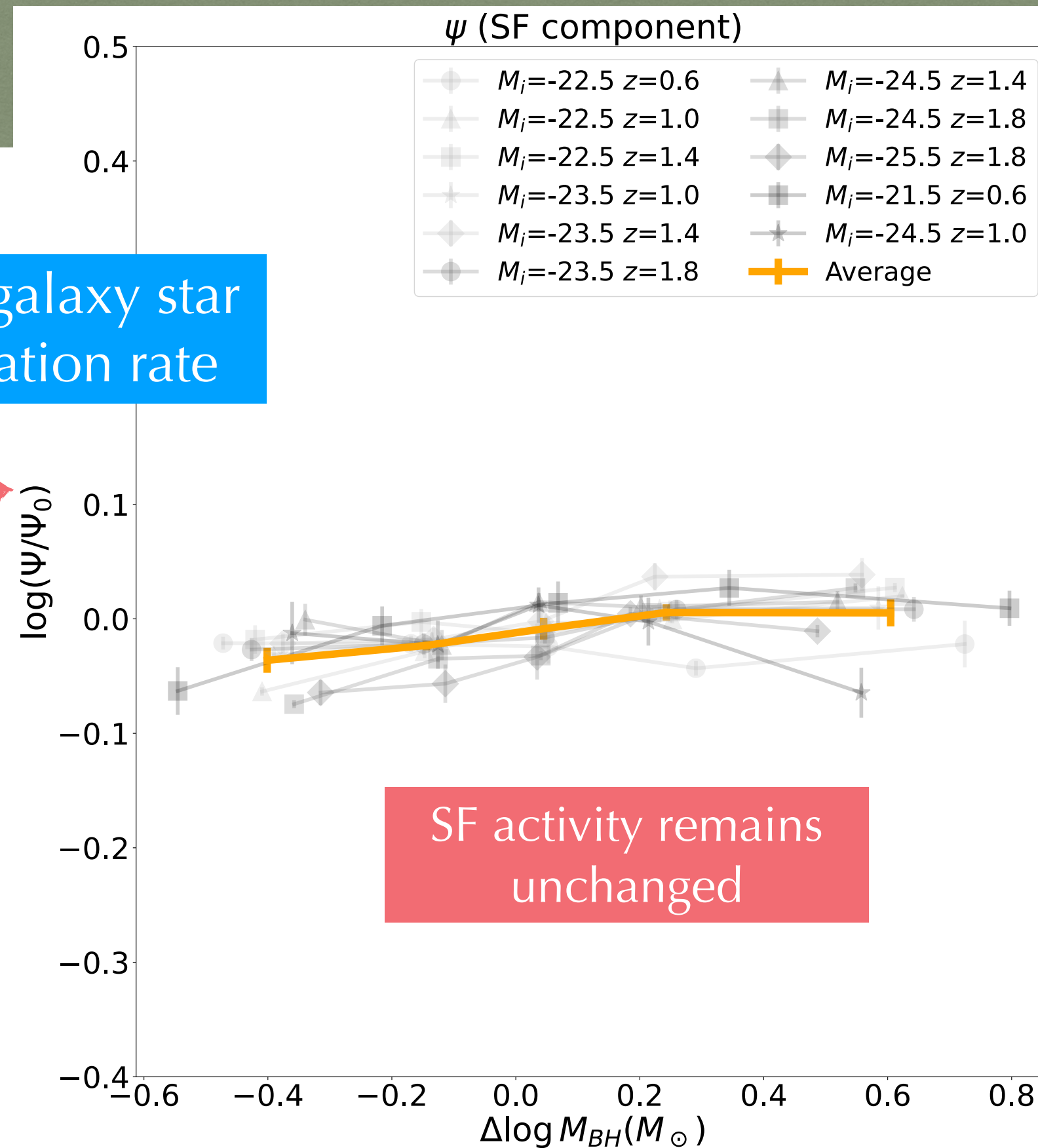
Highest mass quintile QSOs shows difference in flux density distribution

Link to jet power: BH mass

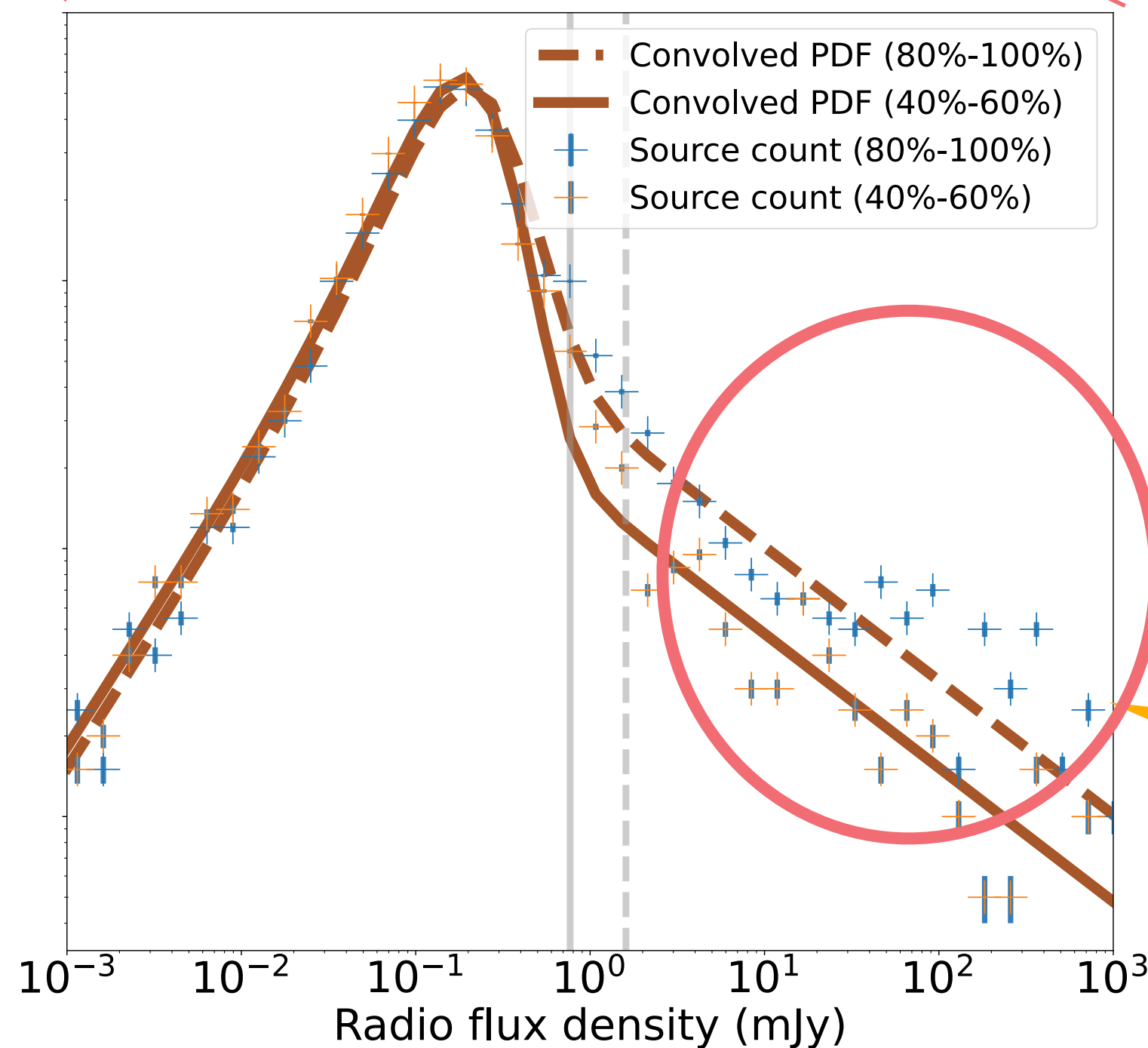
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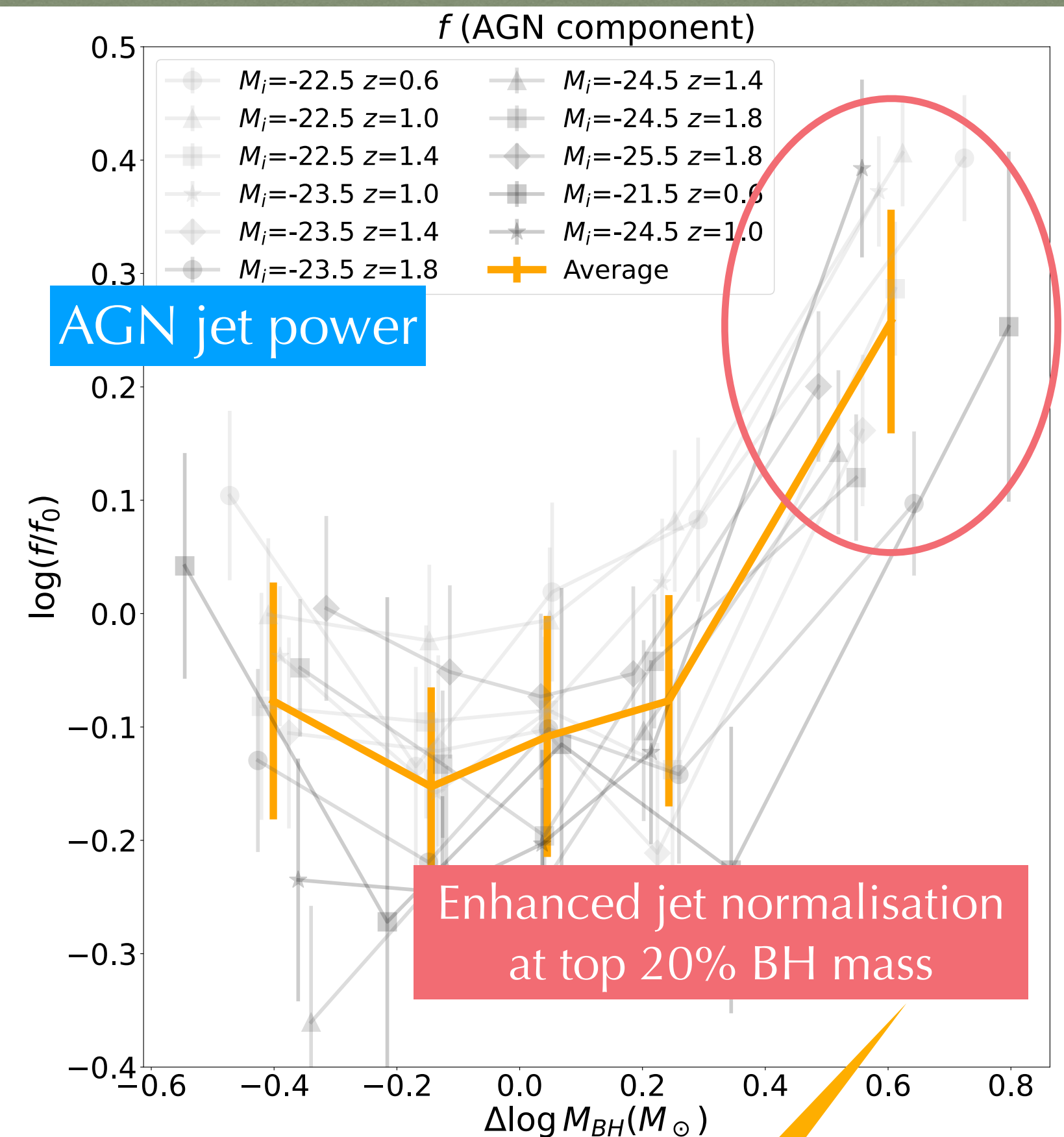
Host galaxy star formation rate



Less massive — BH mass — More massive



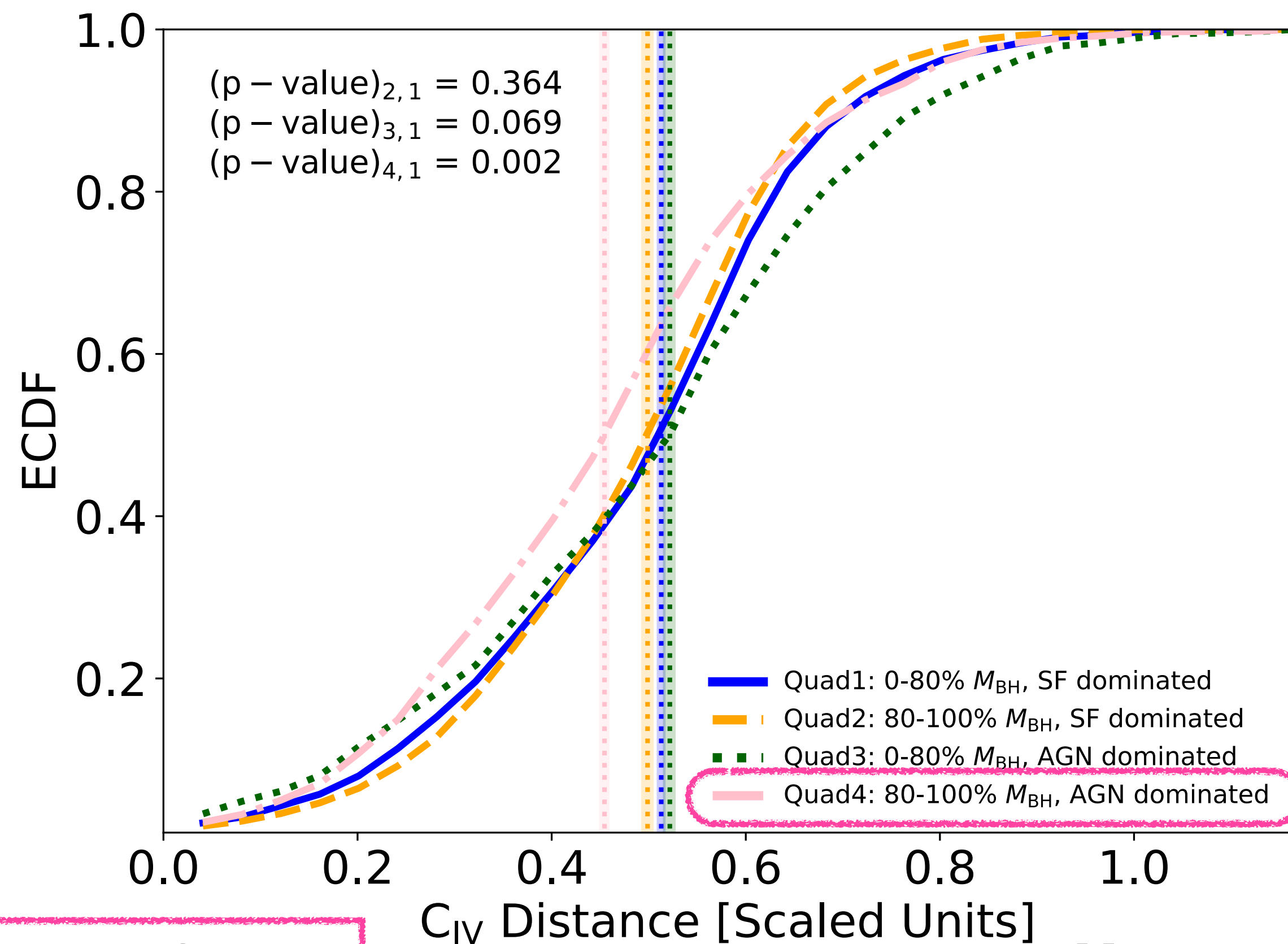
Highest mass quintile QSOs shows difference in flux density distribution



Most massive quasars are **2-3x more likely** to host powerful jets

Link to jet power: BH mass

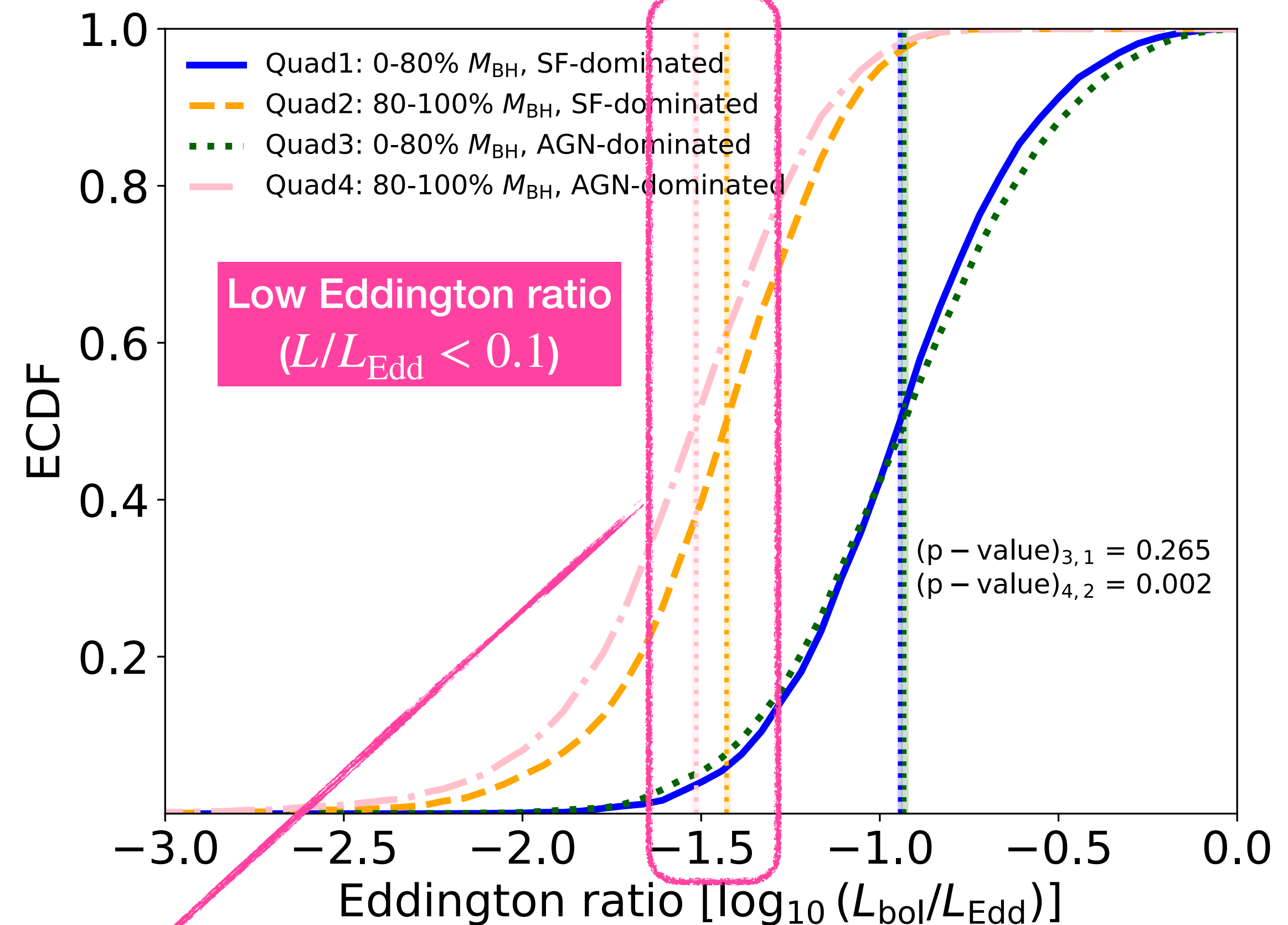
Possible mechanism: accretion mode differences?



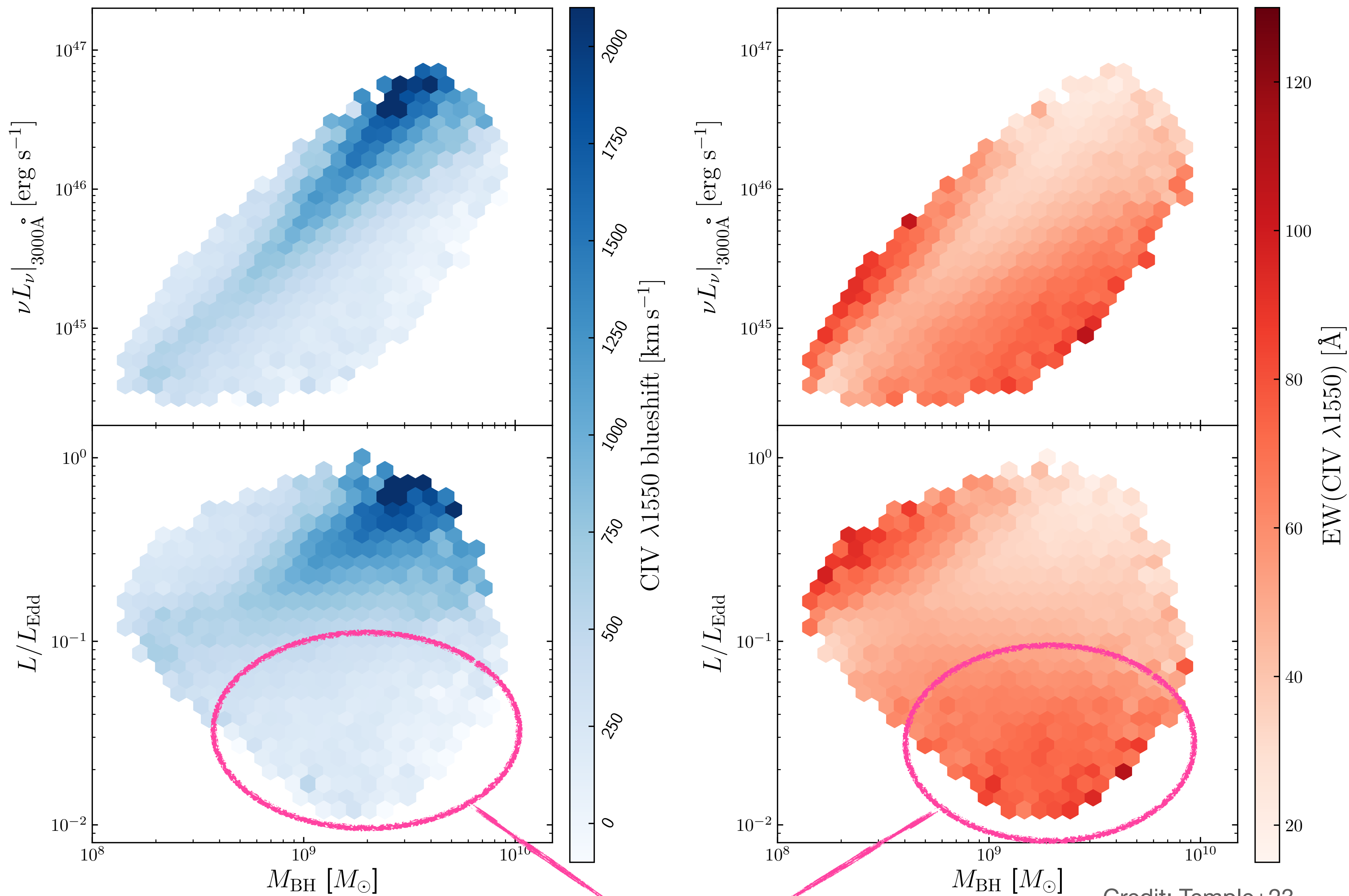
Less outflow
(Kinetic mode)

More outflow
(Radiative mode)

Massive, AGN-dominated QSOs



Link
Possibility



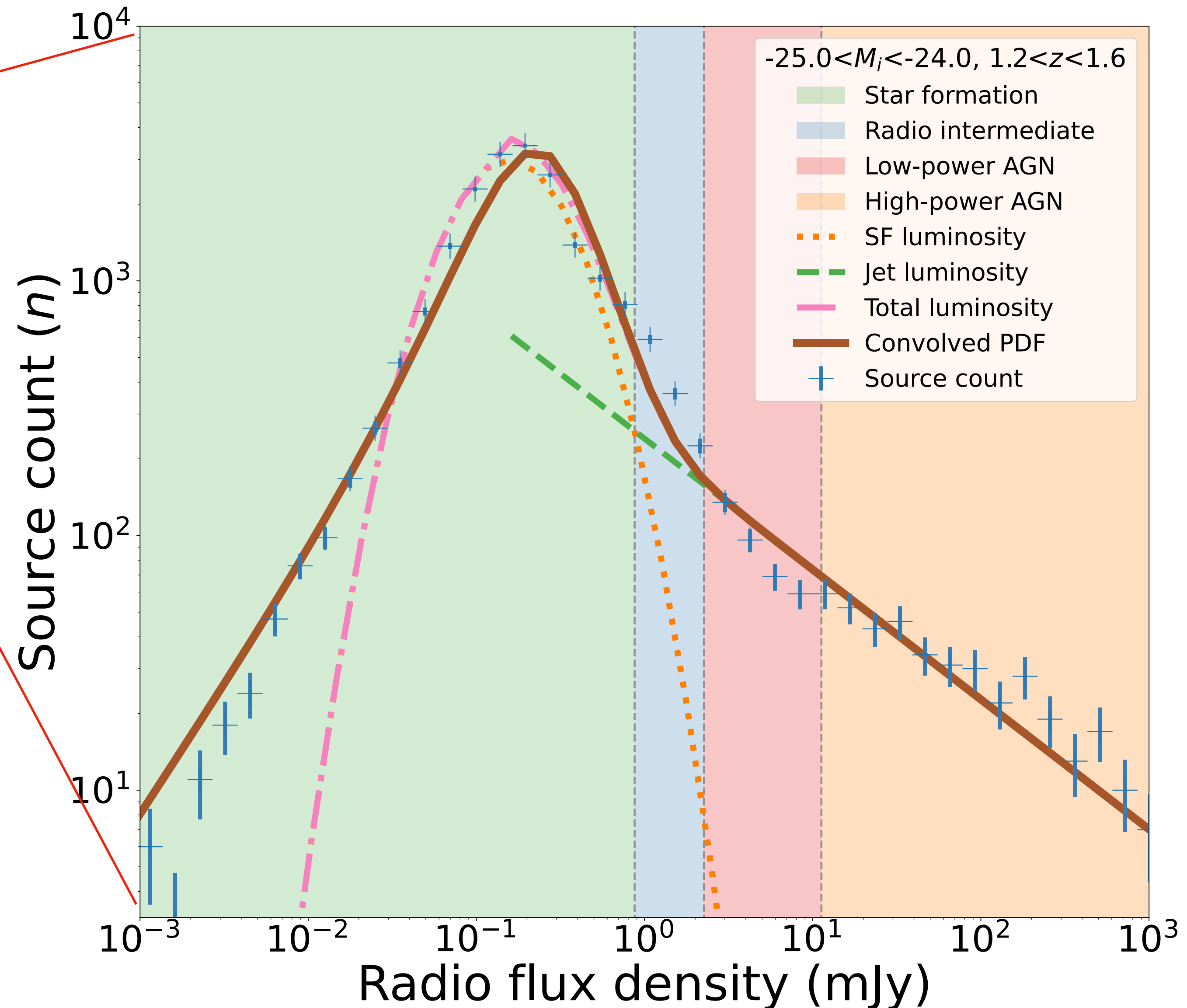
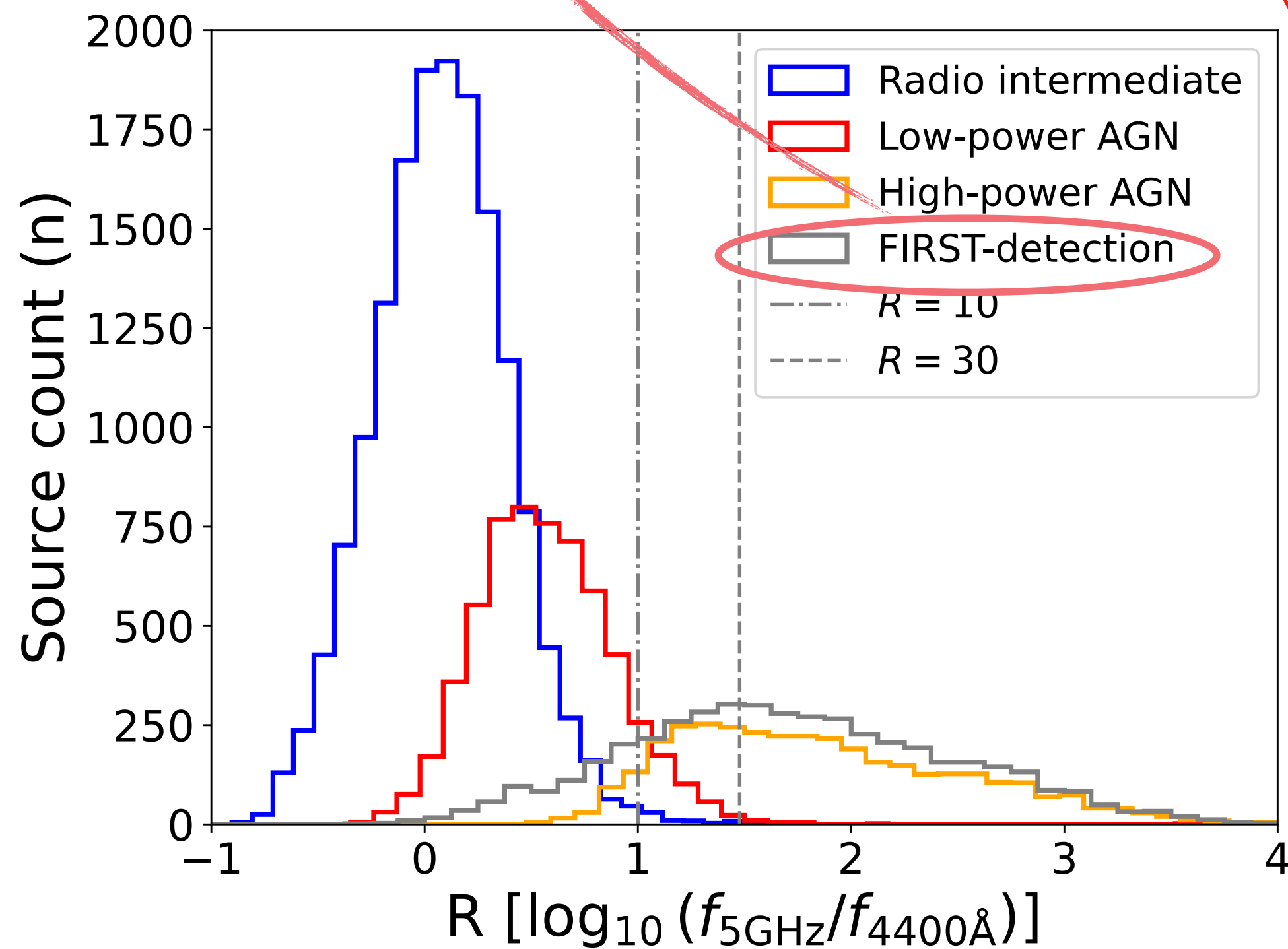
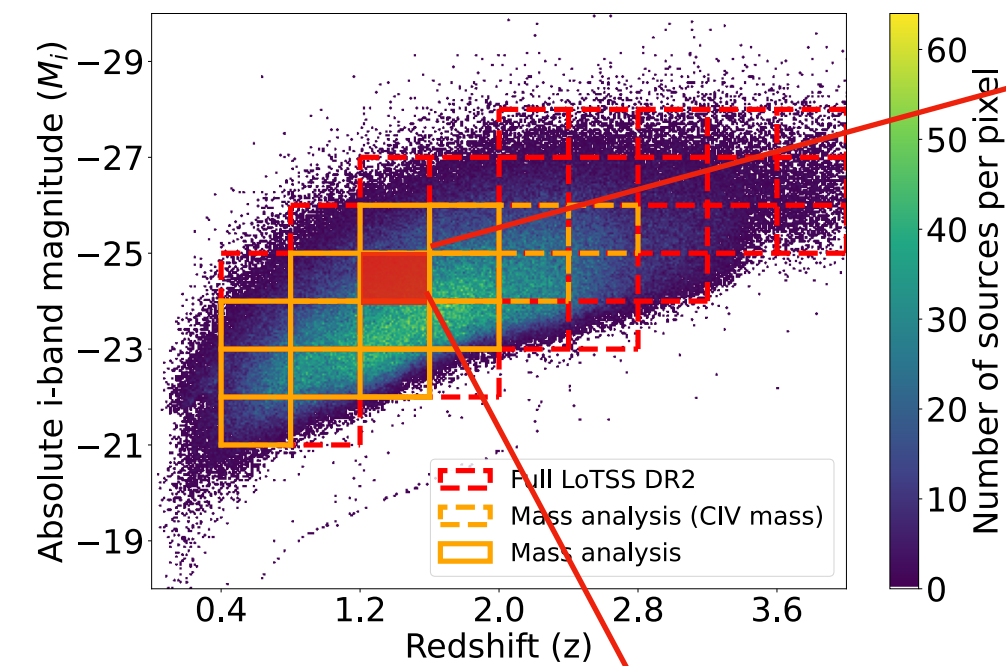
Credit: Temple+23

Massive, AGN-dominated QSOs

Link to jet power: large-scale environment

(Re)-defining radio quasar population

Used in previous radio quasar clustering studies (e.g. Shen+09; Retana-Montenegro+17)



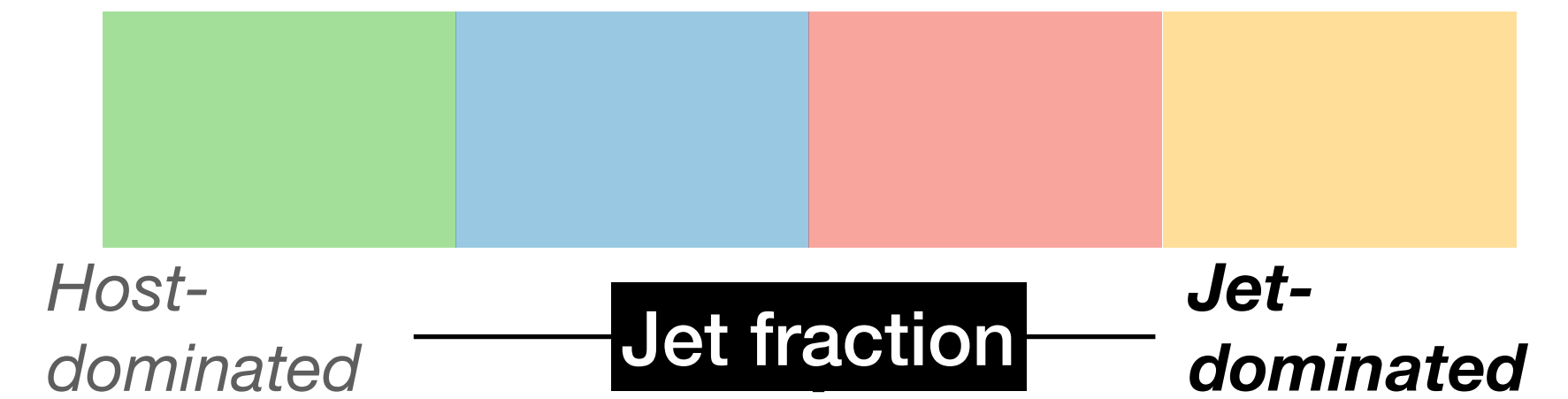
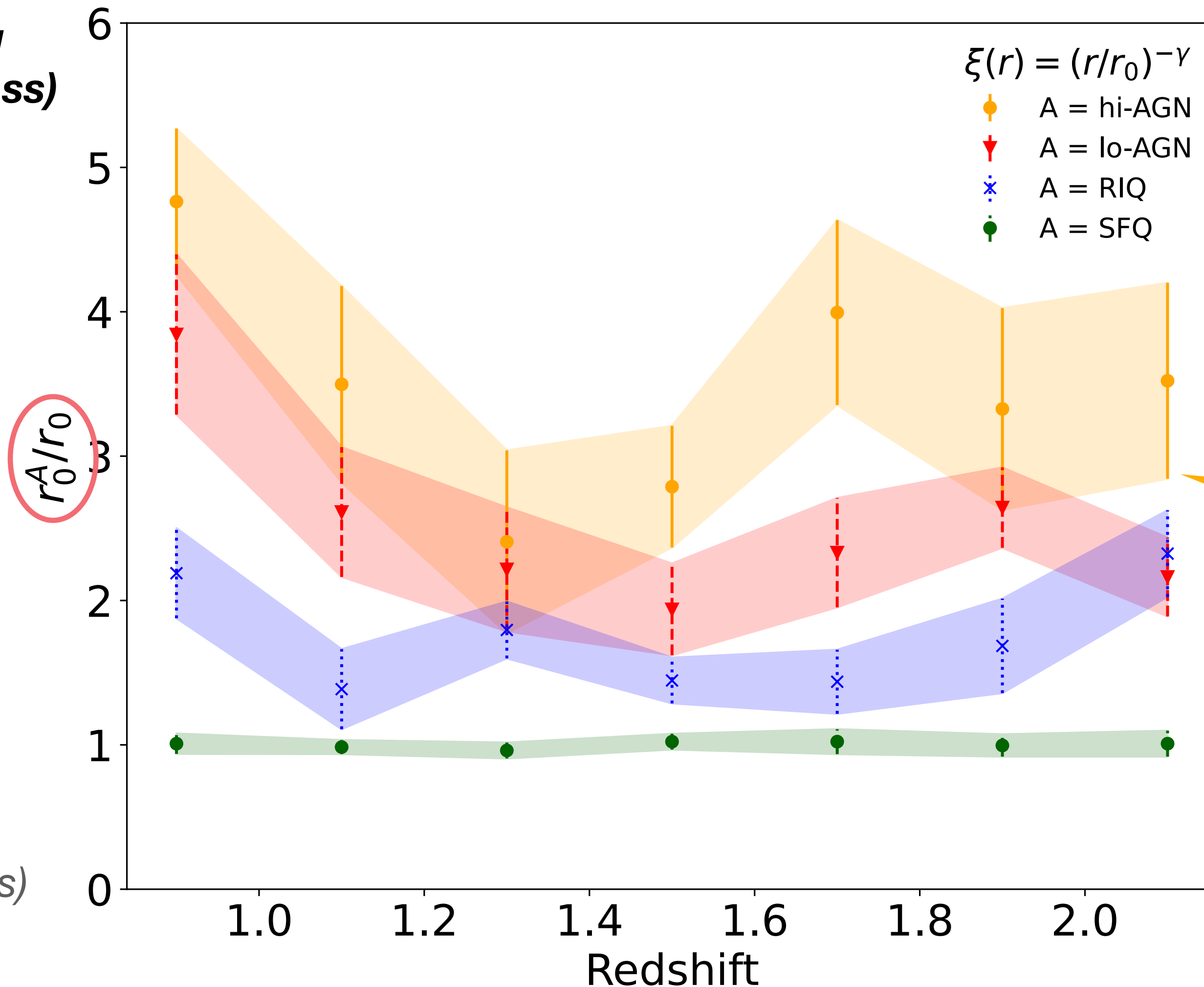
Link to jet power: large-scale environment

Clustering signal from two-point correlation function (TPCF)

More clustering
(higher halo mass)

$r_0 =$
correlation
length of
entire quasar
sample fitted
from TPCF

Less clustering
(Lower halo mass)



Fraction of AGN jet component
in the quasar radio emission

Halo mass is **positively correlated** with
jet fraction in quasar radio emission

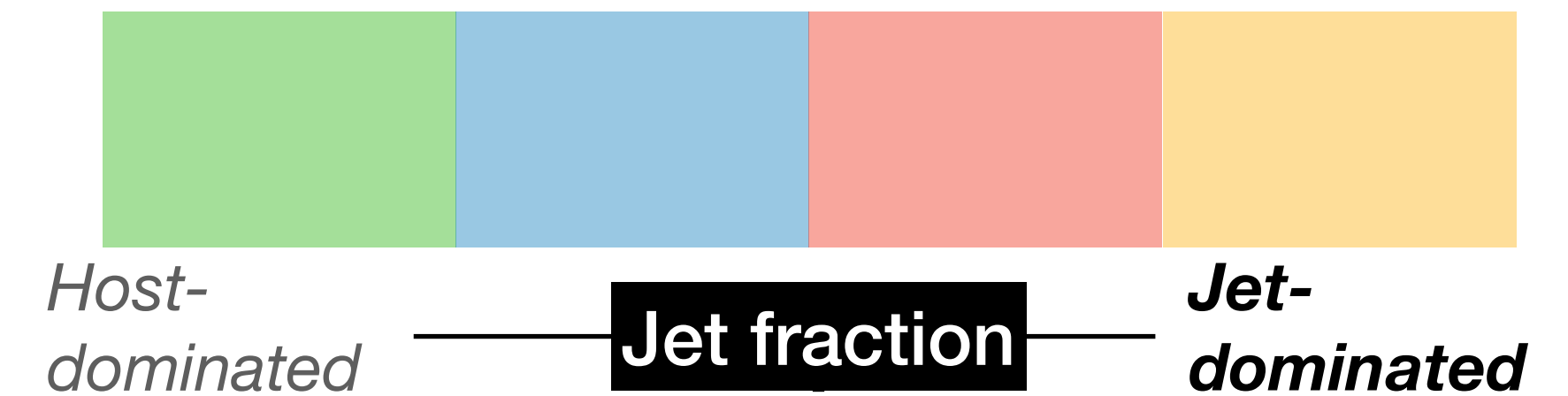
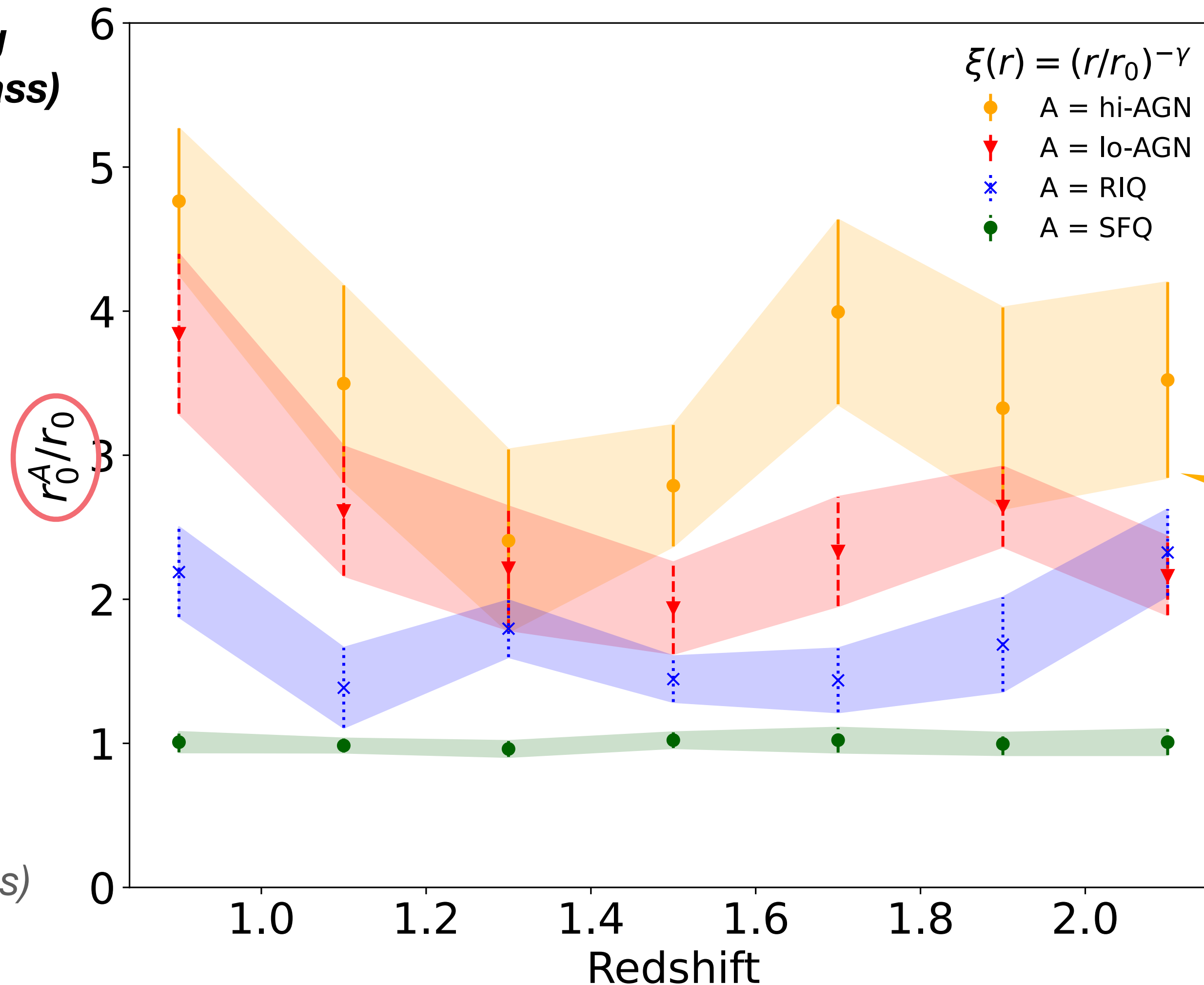
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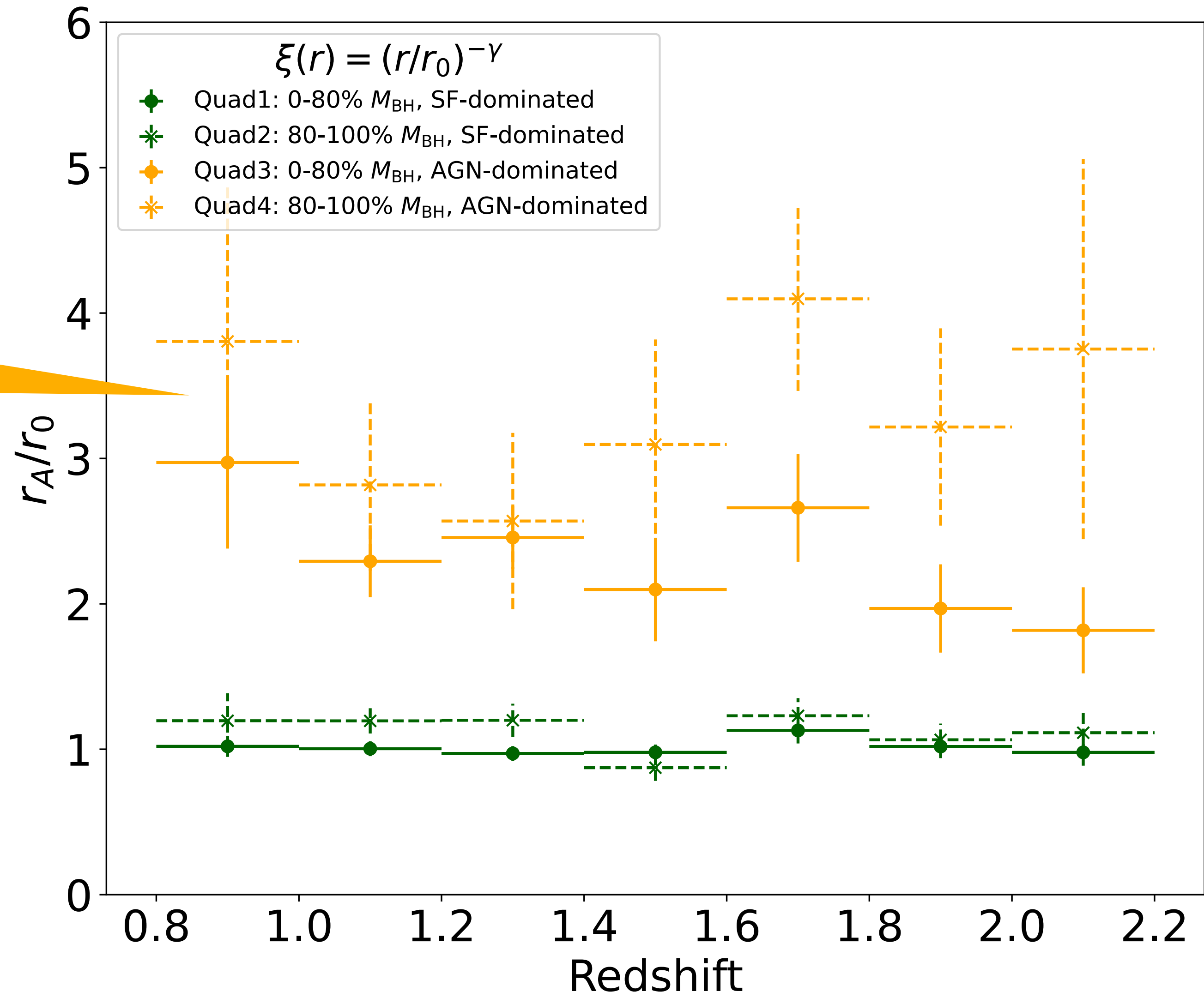
Jet power is **strongly linked** to
the halo gas reservoir

Link to jet power: large-scale environment

Halo mass vs. BH mass

- Are jet-dominated quasars more clustered because of massive haloes or massive BHs?

BH mass / accretion mode alone is not enough to explain the overdensity in jet-dominated quasars



Link to jet power: large-scale environment

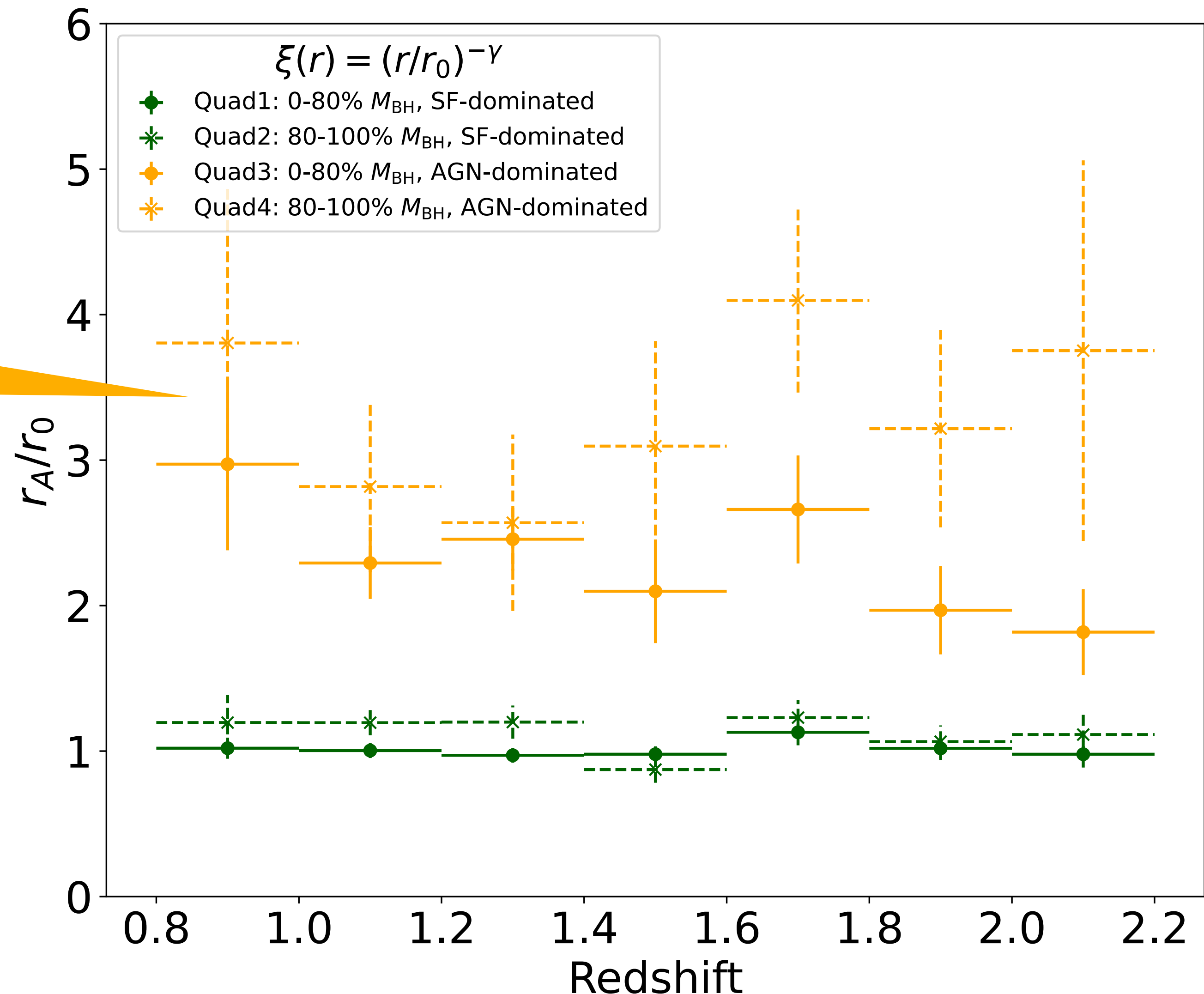
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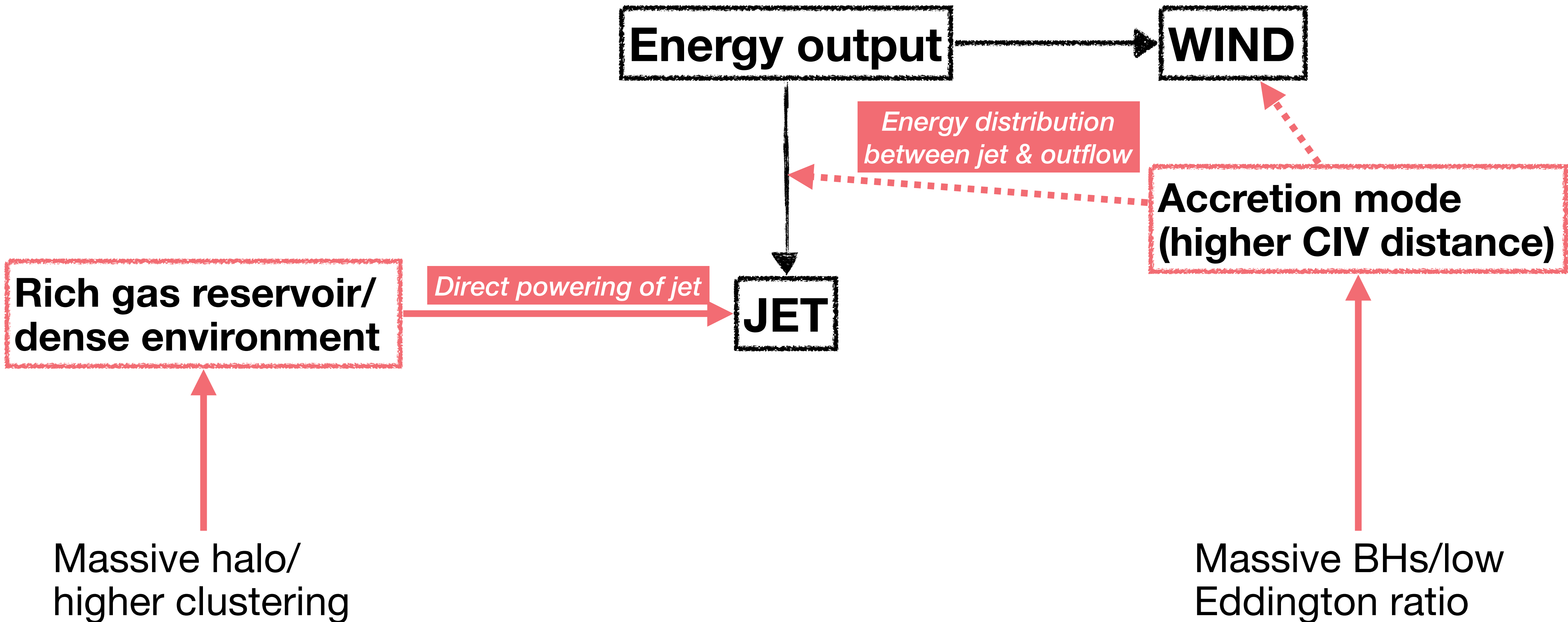
Halo mass > BH mass in determining jet power

More direct powering mechanism?



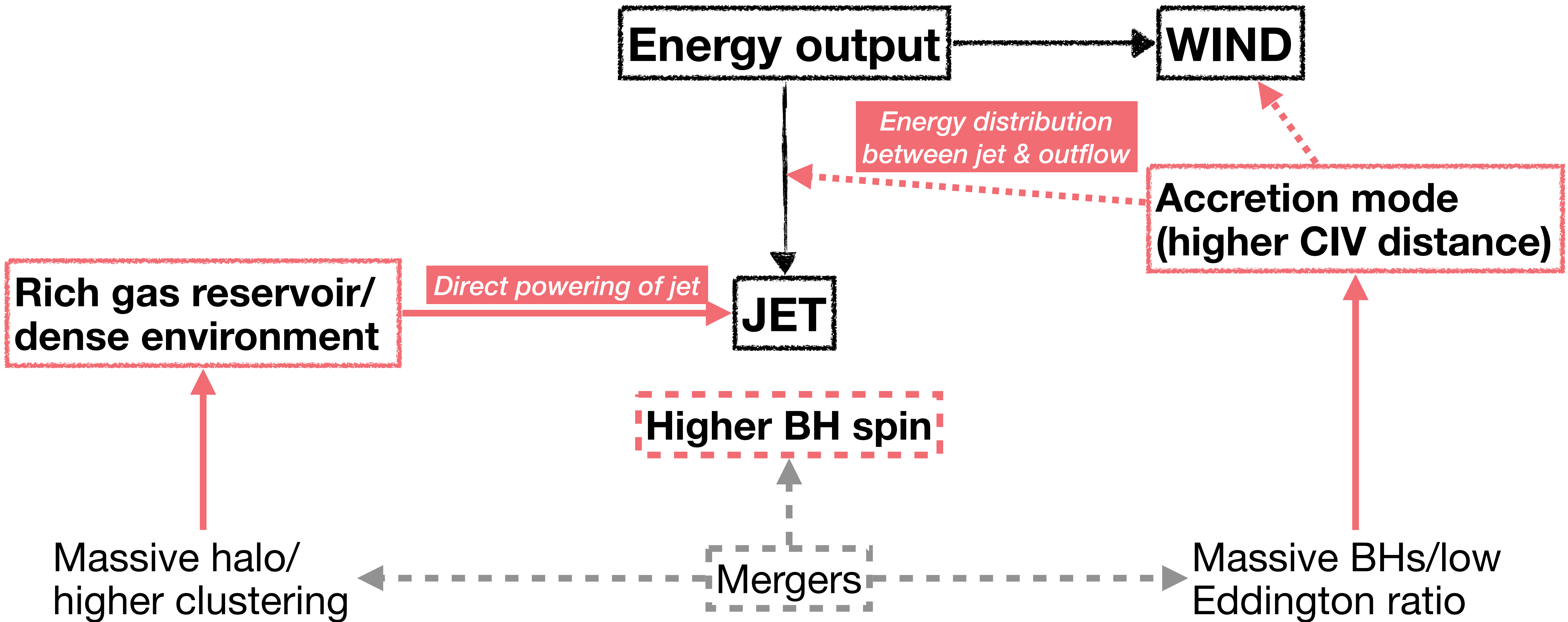
Towards a census of jet powering mechanism

Possible scenarios



Towards a census of jet powering mechanism

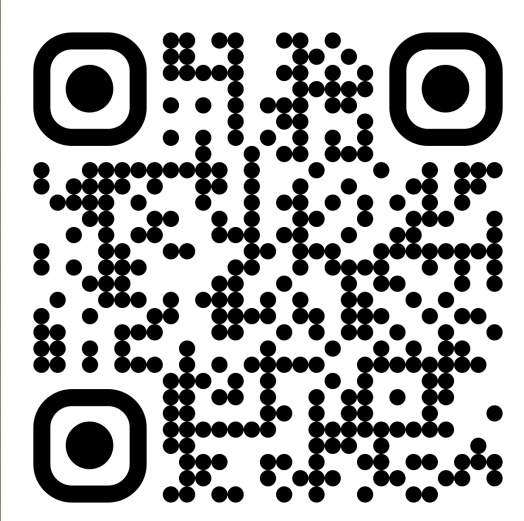
Possible scenarios



*Ongoing project: Joint LOFAR-Euclid
analysis on merger - jet connection!
(w. A. La Marca & L. Wang)*

Take-home messages

...and thanks for listening



- Two-component model can disentangle star-forming component from host galaxies and jet component from AGNs in faint quasar radio emission
- **Radio loudness cannot trace the physical origin of quasar radio emission**
- No significant connection between quasar radio emission and BH mass in both SF and AGN component for most of the sources
- However quasars hosting the most massive (top 20%) SMBHs are 2~3 times more likely to host powerful jets (be AGN dominated); possibly linked with disc-mode accretion, higher BH spins (?)
- **Halo mass is more important than BH mass in determining AGN jet power**
- Please chat with me if you are interested about the application in red/blue QSOs!