ALMA Band 2
A New Window to the Core of High-Redshift Radio-Quiet Quasars

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EUROPEAN ARC
ALMA Regional Centre || Czech

Astronomical Institute of the Czech Academy of Sciences

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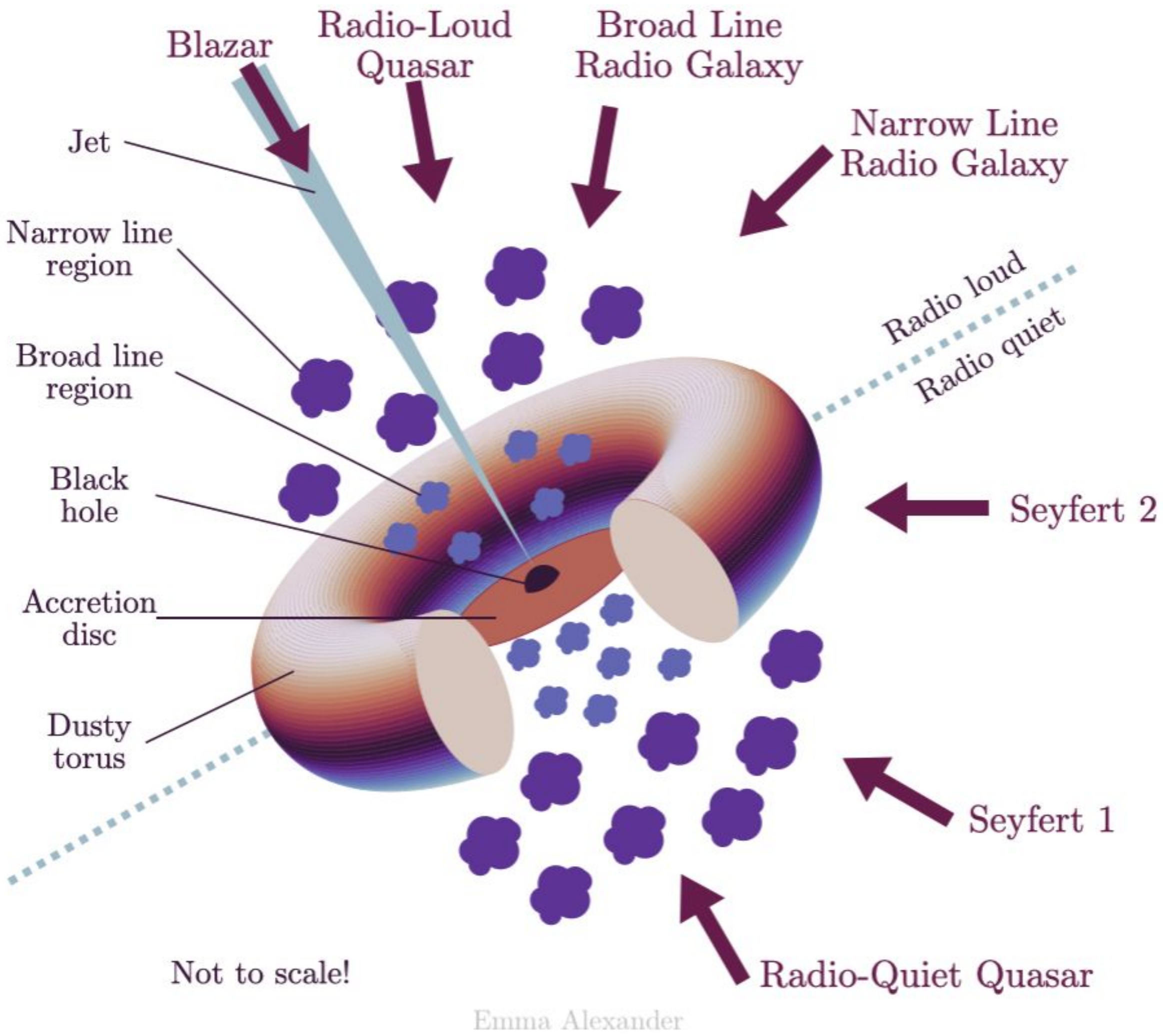
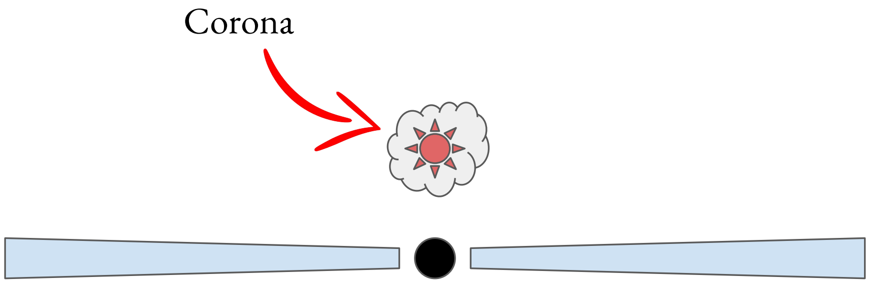
Michal Dovciak, Claudio Ricci,
Taiki Kawamuro and others

AGN in a nutshell

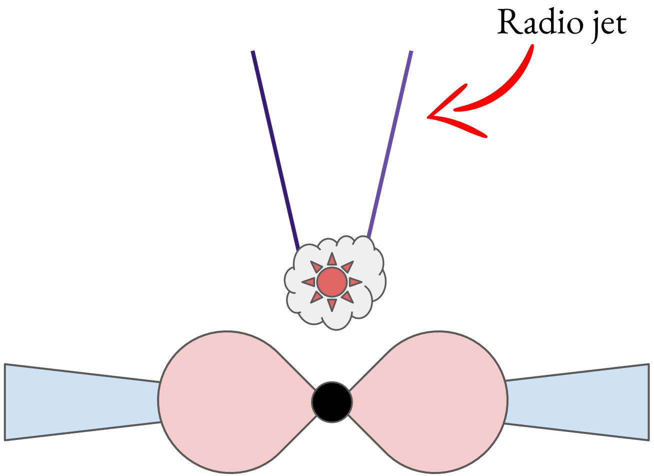


By Emma Alexander
https://commons.wikimedia.org/w/index.php?curid=116390507

Accretion onto the black hole

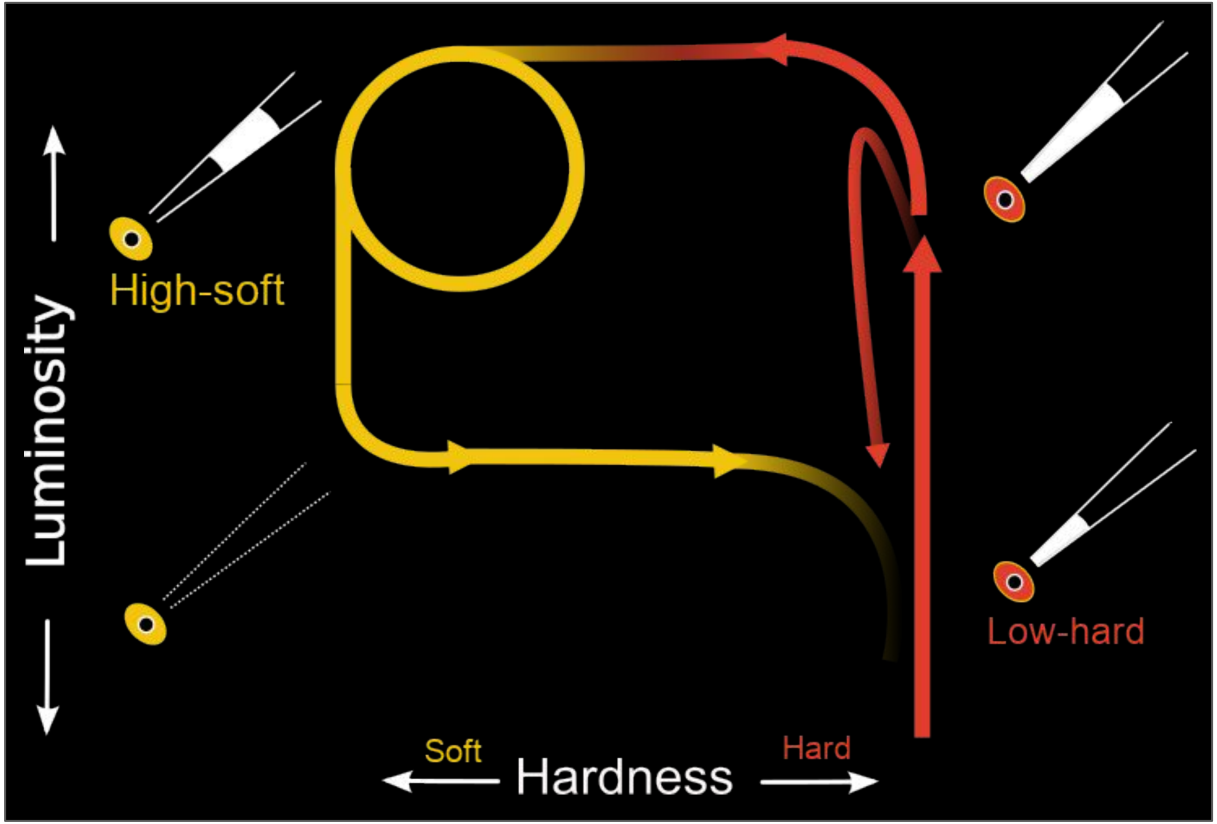


Efficient accretion: geometrically thin, optically thick disk



Inefficient accretion: radiatively inefficient, advection dominated, hot inner accretion flow

The Hardness Intensity Diagram



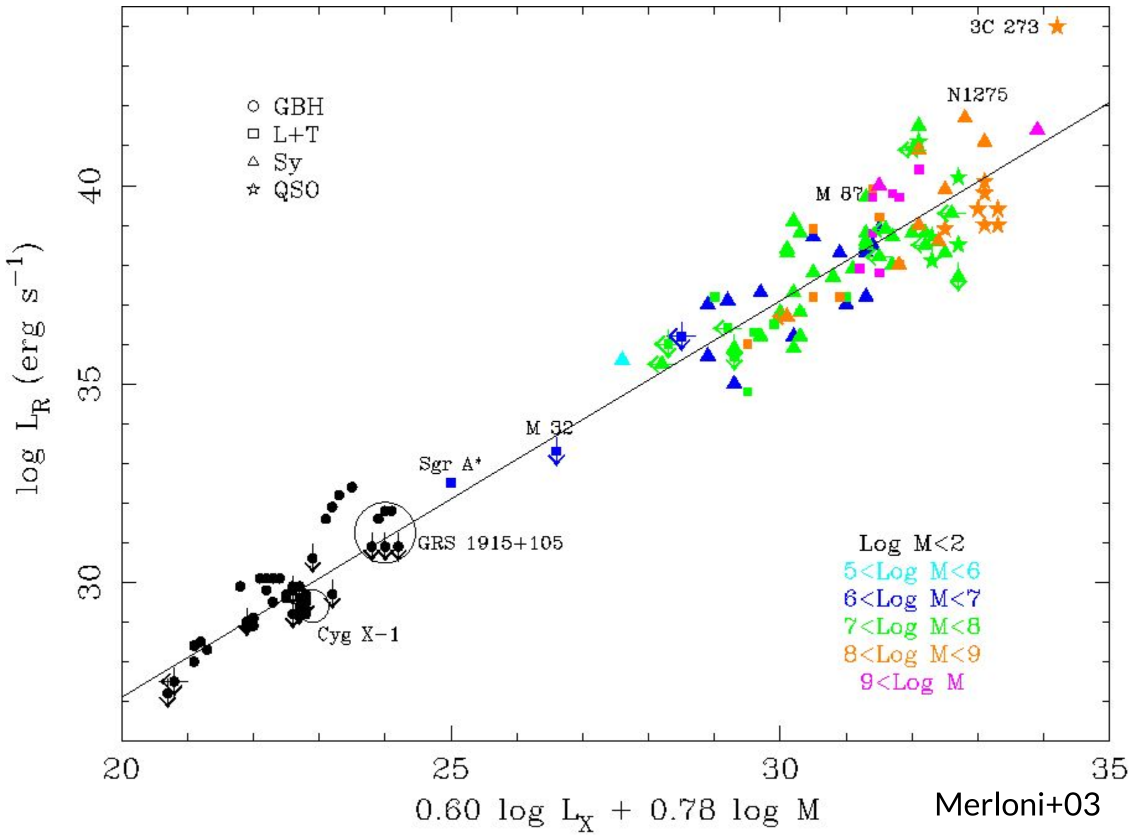
Based on Fender+04, see also Svoboda+17, Moravec+22

How are the X-ray and radio emission connected?

The Fundamental Plane of Black Hole accretion

For X-ray binaries (Gallo+03)

$$L_R \propto L_X^{0.7}$$



Merloni+03

Why is millimeter regime important?

1. **Catching the synchrotron tail:** Probing the optically thin synchrotron emission from the region close to the central engine.

2. **Access to higher resolution:** Angular resolution is proportional to the observing wavelength.

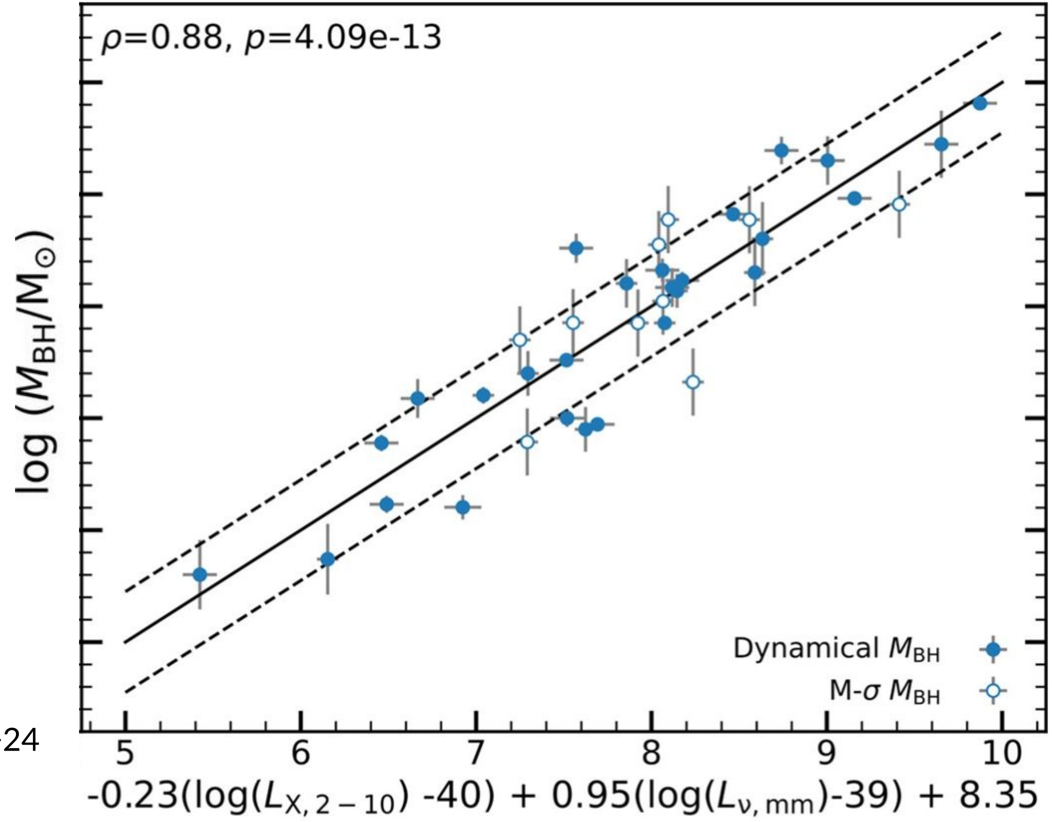
3. **Transparency to dust:** synchrotron emission is not suppressed by the environment (e.g. torus) and galactic dust. Thermal dust emission becomes more prominent at higher frequencies.

4. **Broadband SED:** Even at lower angular resolution, (sub-)mm SED measurement helps with determining contributions from different physical processes (see the next talk by del Palacio).

How are the X-ray and radio emission connected?

The Fundamental Plane relation in millimeter wavelength, derived mainly from local moderately accreting AGN.

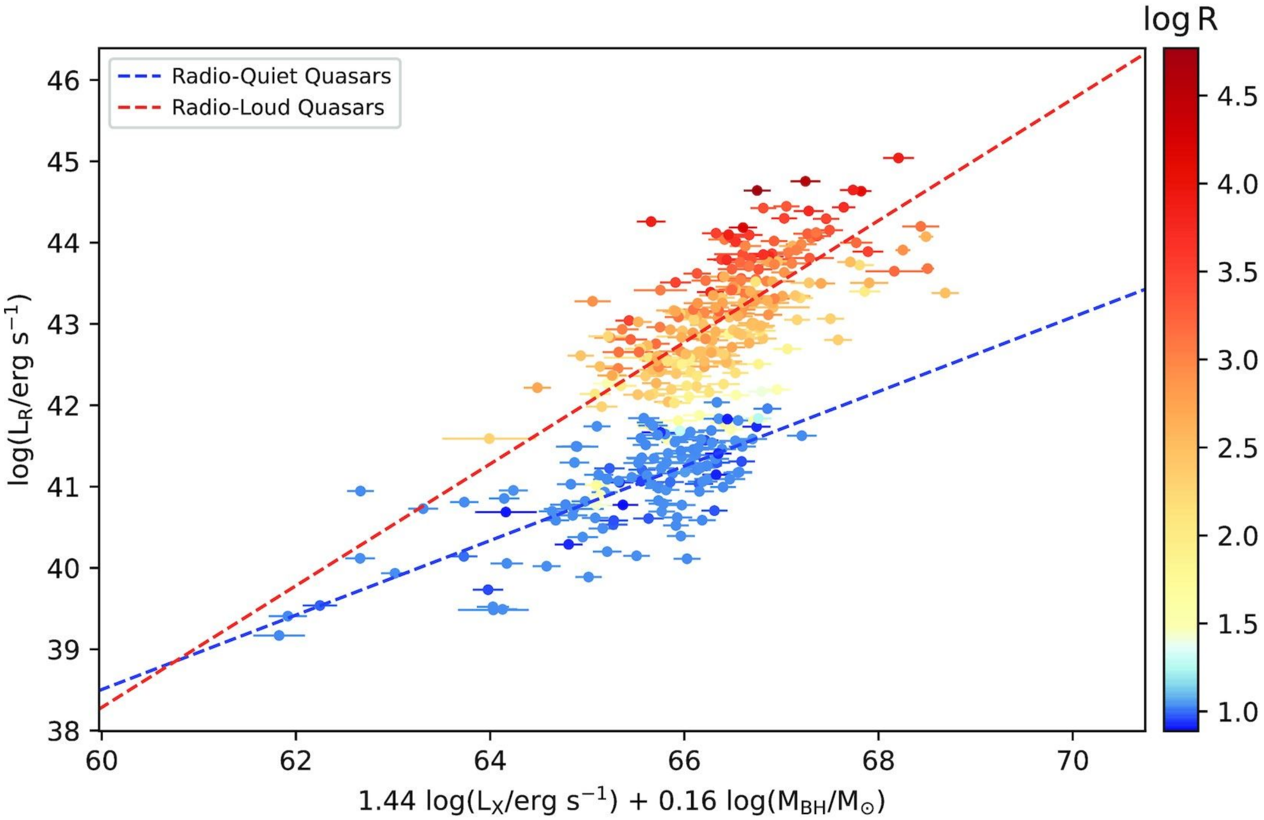
Relation is best explained by ADAF like model, suggesting a radiatively inefficient process.



Ruffa+24

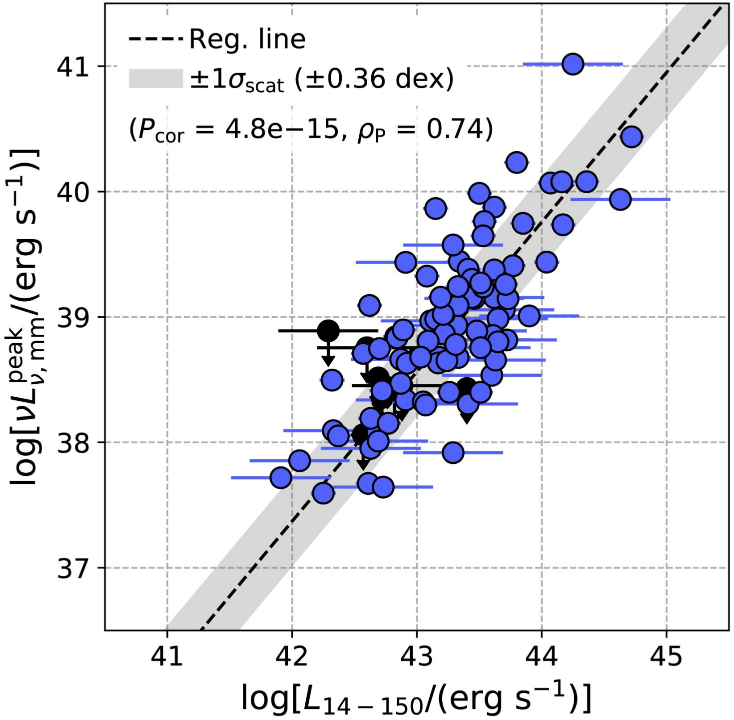
How are the X-ray and radio emission connected?

The Fundamental Plane of Black Hole accretion for radio loud and radio quiet AGN

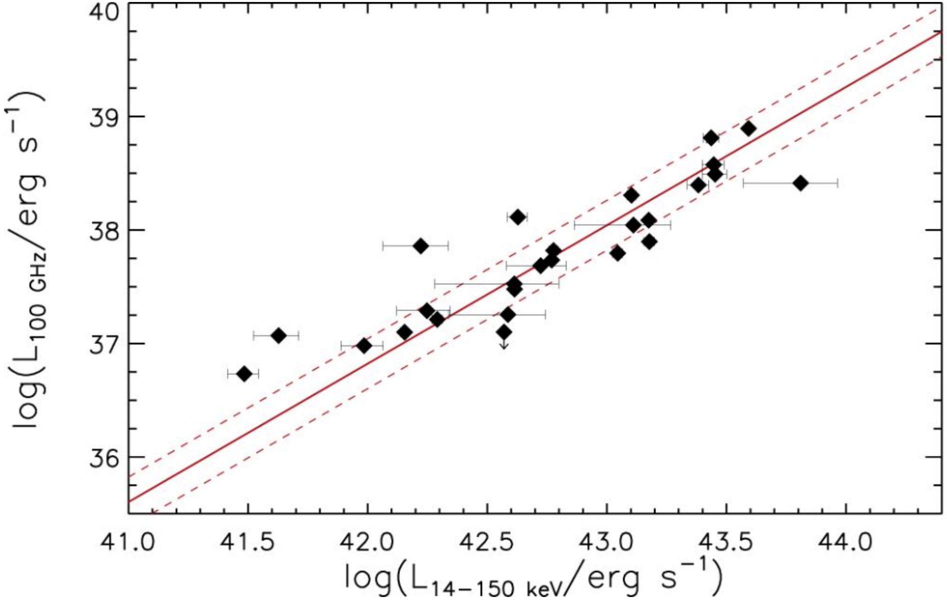


Bariuan+22
See also Wang+24

Millimeter - X-ray connection



Kawamuro+22



Ricci+23

Also see Rybak+25, del Palacio+25

Why high-z AGN?

- **The Cosmic Noon:** Peak of AGN accretion and star formation around $z \sim 1 - 3$.

- **Evolution of the FP relation:** Are the FP relations consistent over the cosmic timescales, does the scaling change over time?

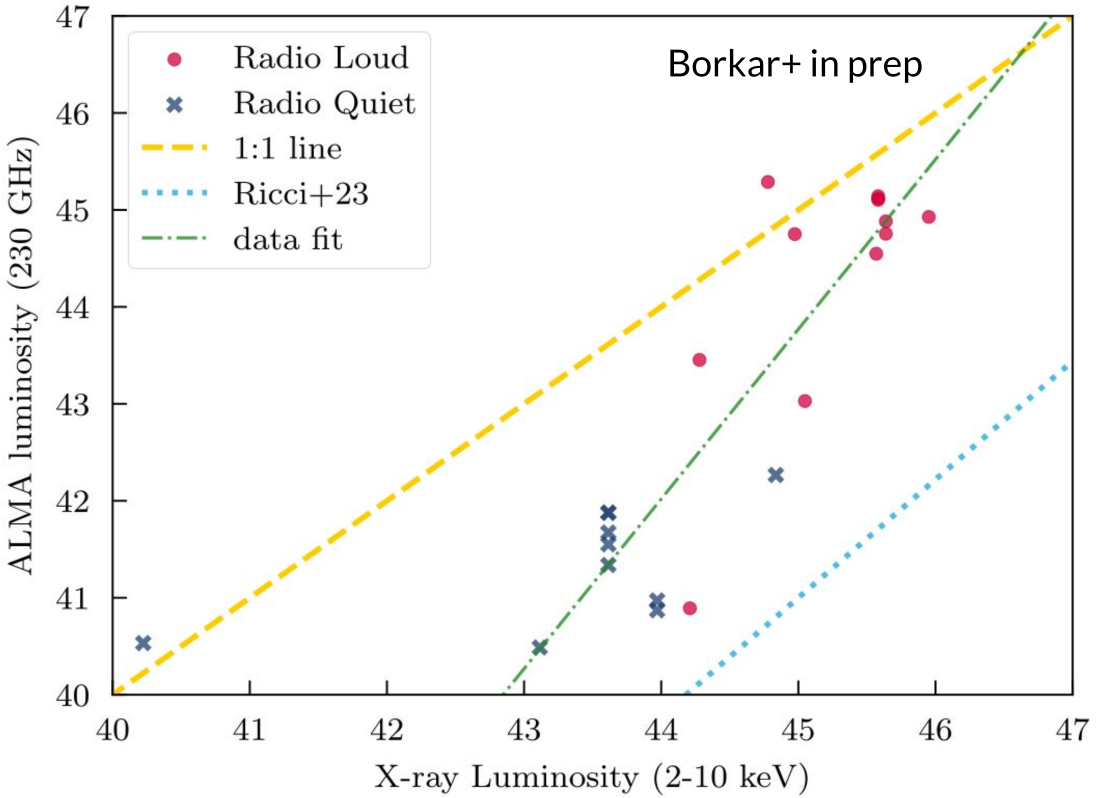
- **Hidden AGN:** SMBH growth often happens in under strong obscuration, such AGN are hard to detect using traditional methods (optical, X-ray).

Millimeter – X-ray correlation for high-z sources

Heterogeneous sample of SDSS quasars from archival ALMA observations.

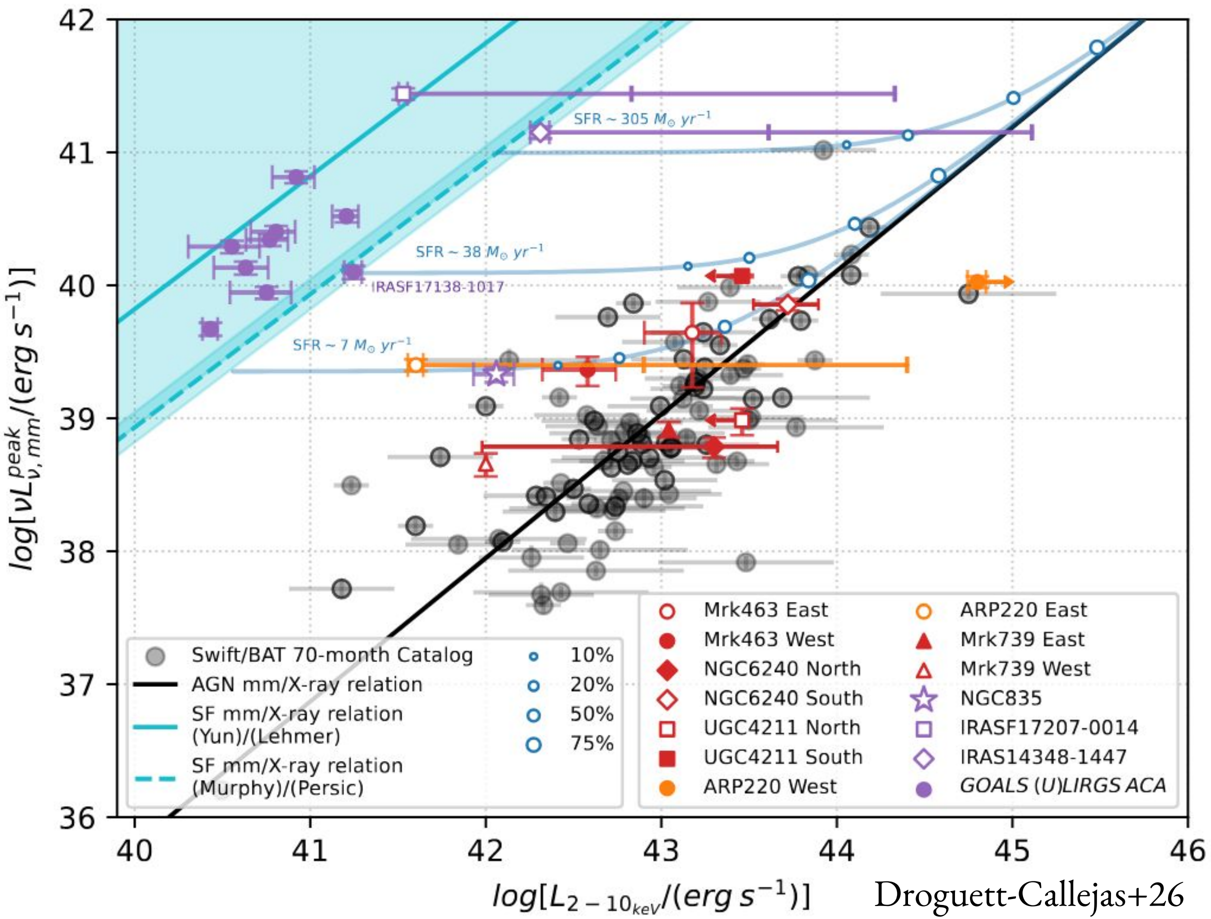
RL quasars likely dominated by jet emission.

Host emission likely contributes to RQ quasar.



Millimeter and X-ray relation to detect the presence of AGN in star-forming galaxies.
(e.g. Droguett-Callejas+26).

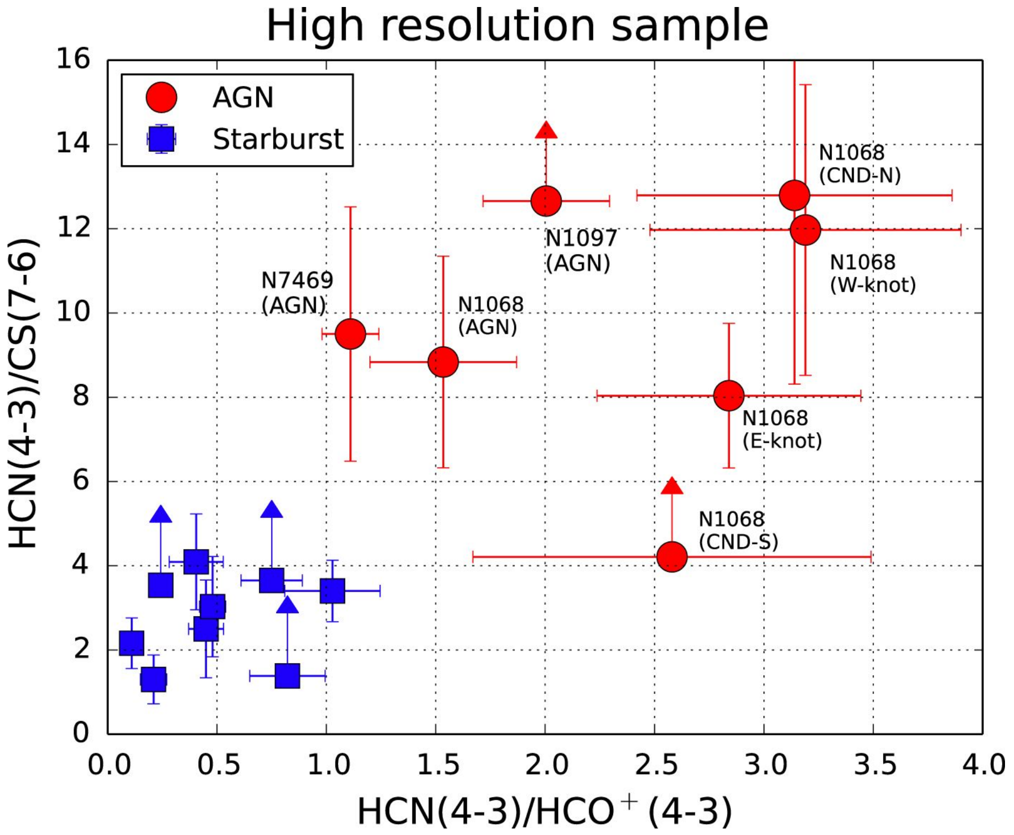
Millimeter FP relation to estimate SMBH masses.



Droguett-Callejas+26

The submillimeter HCN diagram

- For the identification of AGN activity in heavily obscured sources and differentiating from starburst galaxies.
- Ideally, rest-frame band 7 observations at high angular resolution are required.
- Lower transitions of HCN and HCO+ show a similar divergence, just not as prominent.



Summary

- There is a robust correlation between the millimeter, radio and X-ray emission from AGN

- ALMA Band-2 observations will provide a new window into quasar cores by:
  - Identifying obscured AGN at high redshifts through millimeter luminosity, SED modelling, and submillimeter HCN diagnostics diagram.
  - Estimating SMBH masses via the Fundamental Plane relation.
  - Probing the physical link between radio/millimeter emissions and the X-ray corona in both RL and RQ populations.

- Limited spatial resolution at high redshifts may present a significant challenge for scaling these methods to larger samples.