ŚWIATOWY KONGRES KOPERNIKAŃSKI

NICOLAUS COPERNICUS WORLD CONGRESS

Jet Activity of Supermassive Black Holes

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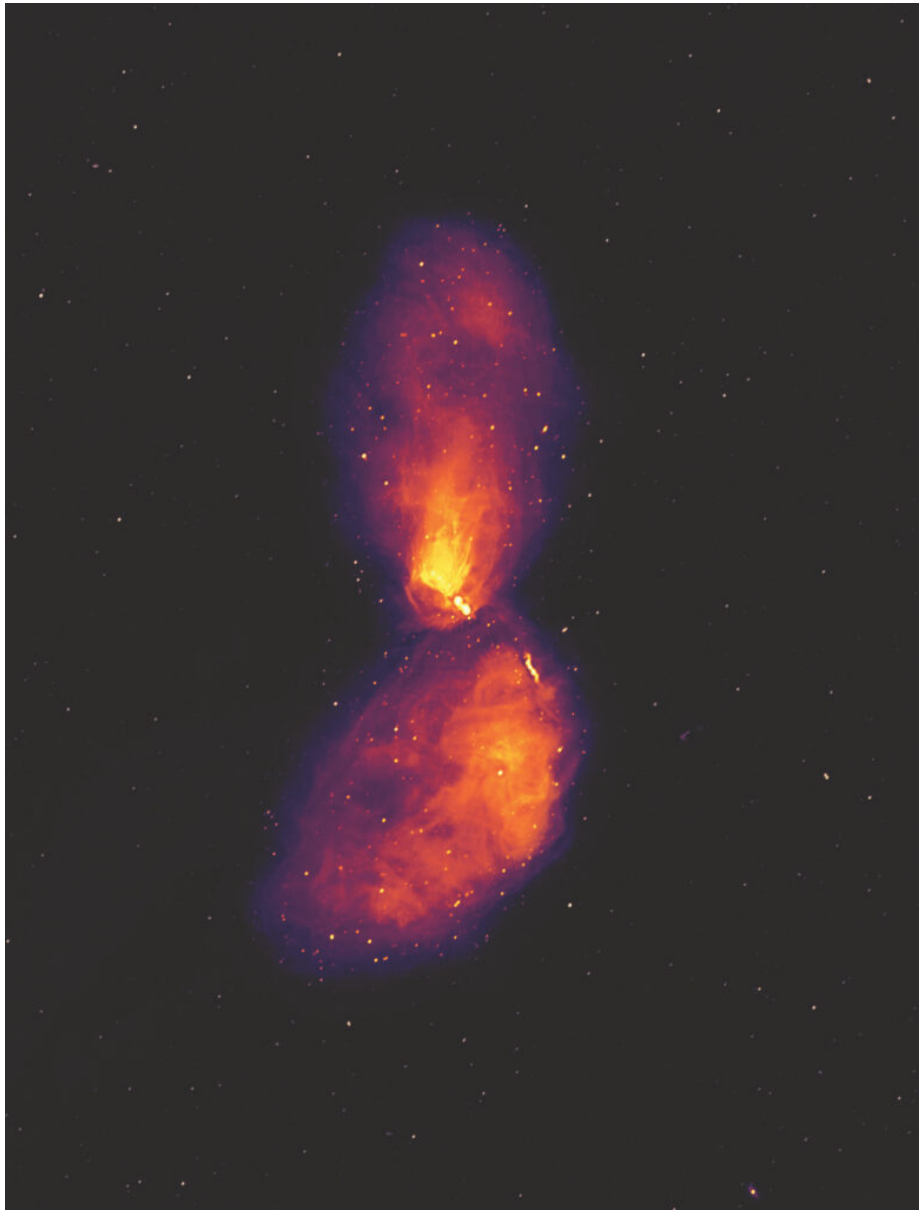
Radio Emission of Galaxies

- **starforming regions**
  galaxies differ in the rate of starformation, from starburst systems with SFR ~ 100–1,000 $M_\odot$/yr, to evolved ellipticals with SFR ~ 0.1–1 $M_\odot$/yr

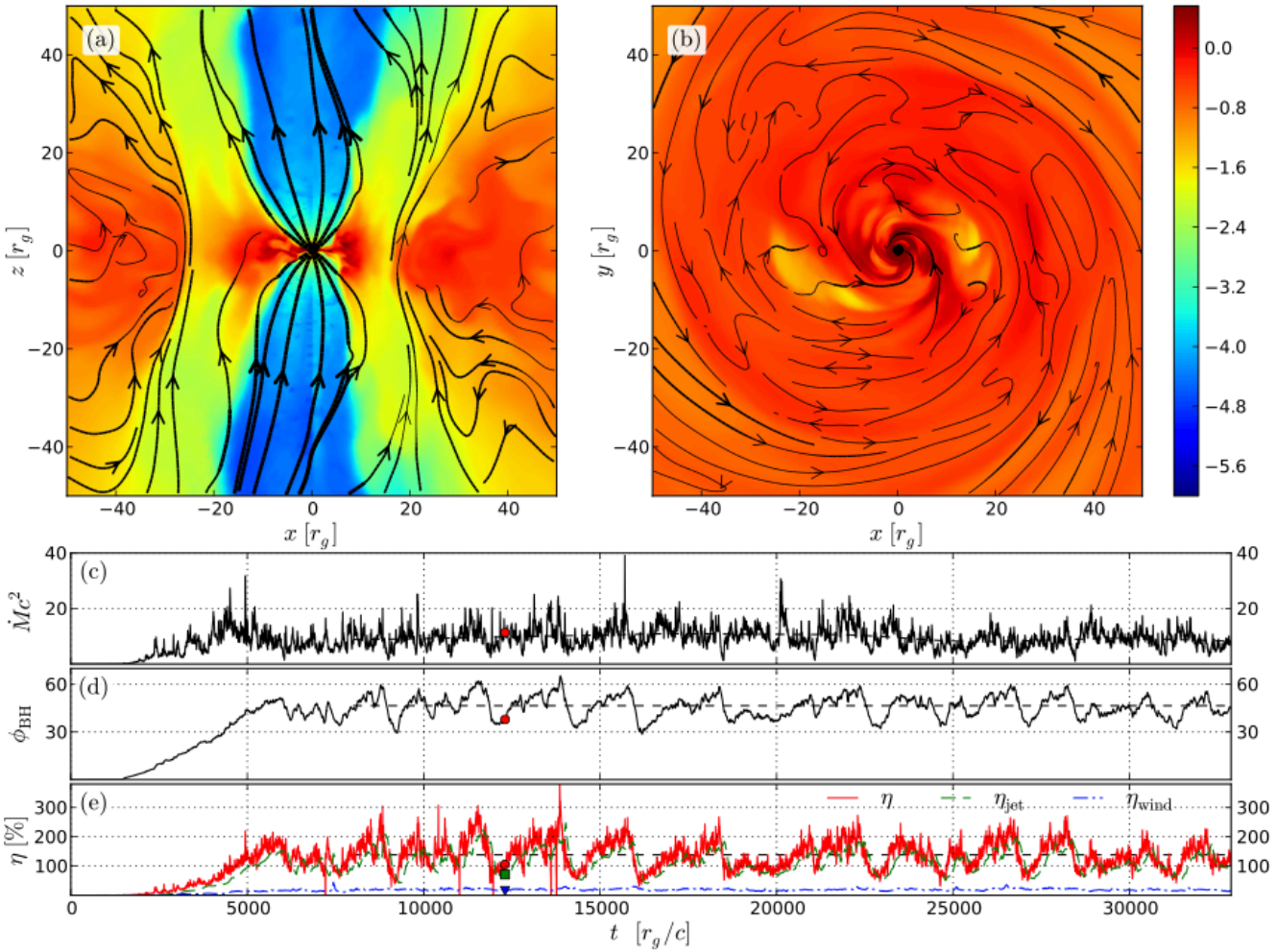
- **jet activity of central supermassive black holes (SMBH)**
  galaxies differ in BH masses and nuclear accretion rates

Murchison Widefield Array (MWA)



Blandford & Znajek 1977

- **extraction of a SMBH rotational energy** by magnetic fields supported by accreting matter and entering the BH ergosphere
- $L_j \propto \Phi_{\rm B}^2 \; f(J_{\rm BH}) \quad \rightarrow \quad \sim \dot{M}_{\rm acc} c^2 \, a^2$
  where $a = cJ_{\rm BH}/GM_{\rm BH}^2$
- well supported by **GR MHD simulations**



Tchekhovskoy et al.

Basic Questions

- **all galaxies are active at some level!**
  nuclear accretion rates differ however widely from ~Eddington in quasar sources, to $\ll 10^{-5}$ in low-luministy AGN

- **are all galaxies jetted?**
  does the jet distribution reflect directly the nuclear accretion rate distribution of galaxies?

- **why the jets can appear so different among galaxies with similar nuclear accretion rates?**
  is it due to different spin values? or magnetization properties of the hosts?

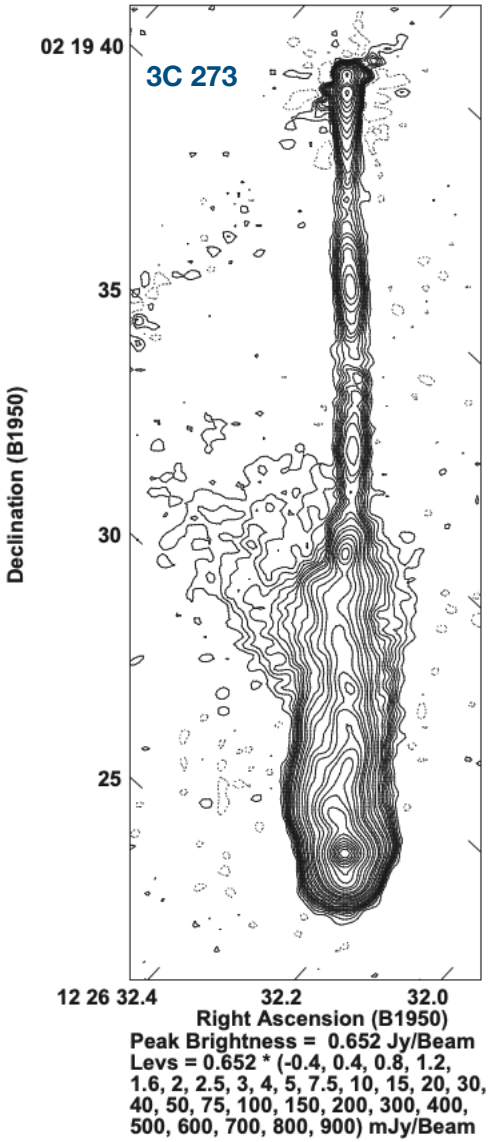
$$L_{\rm Edd} = \frac{4\pi G m_p c M_{\rm BH}}{\sigma_T} \simeq 10^{46} \left(\frac{M_{\rm BH}}{10^8 M_\odot} \right) \ {\rm erg\ s^{-1}}$$

$$\lambda = \frac{L_{\rm acc}}{L_{\rm Edd}}$$

$$R = \frac{L_{\nu,\,\rm R}}{L_{\nu,\,\rm B}} \quad \rightarrow \quad \text{by assumption} \quad R \propto \frac{L_{\rm j}}{L_{\rm acc}}$$

Quasars

- quasars are cosmologically distant, **high accretion-rate** galaxies, $\lambda > 0.01$
- some produce bright, **extremely luminous radio jets** extending far outside host galaxies, up to even Mpc scales
- some are undetected in radio, or display only unresolved radio cores; **jet intermittency or some intrinsic differences in the central engine?**



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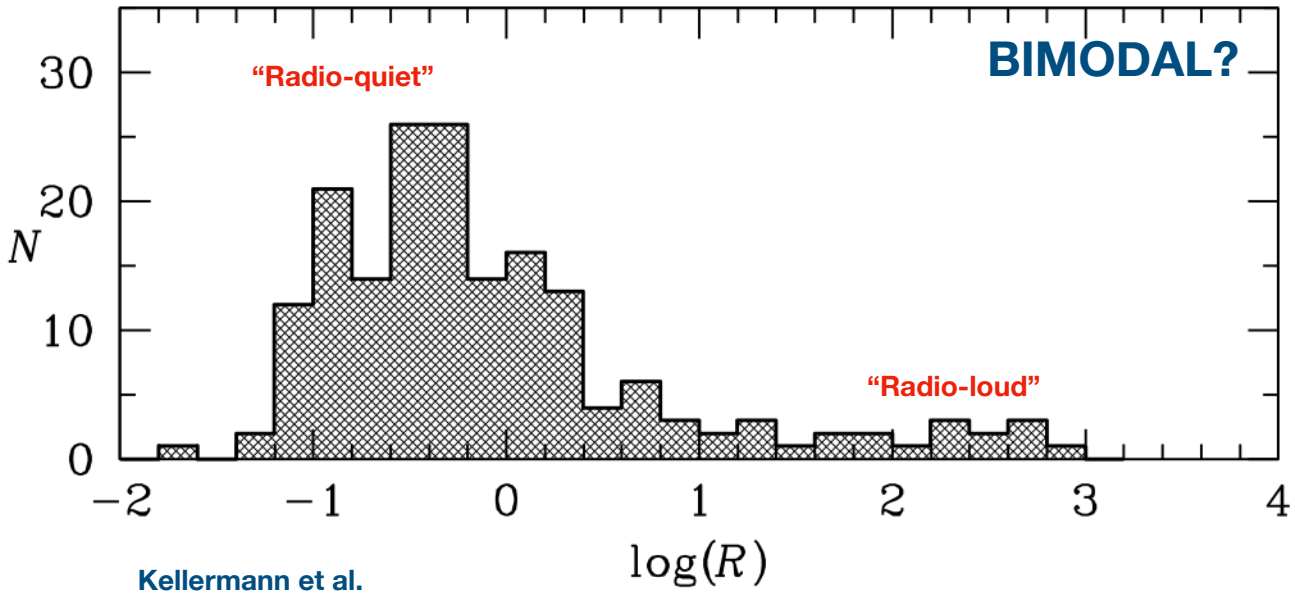
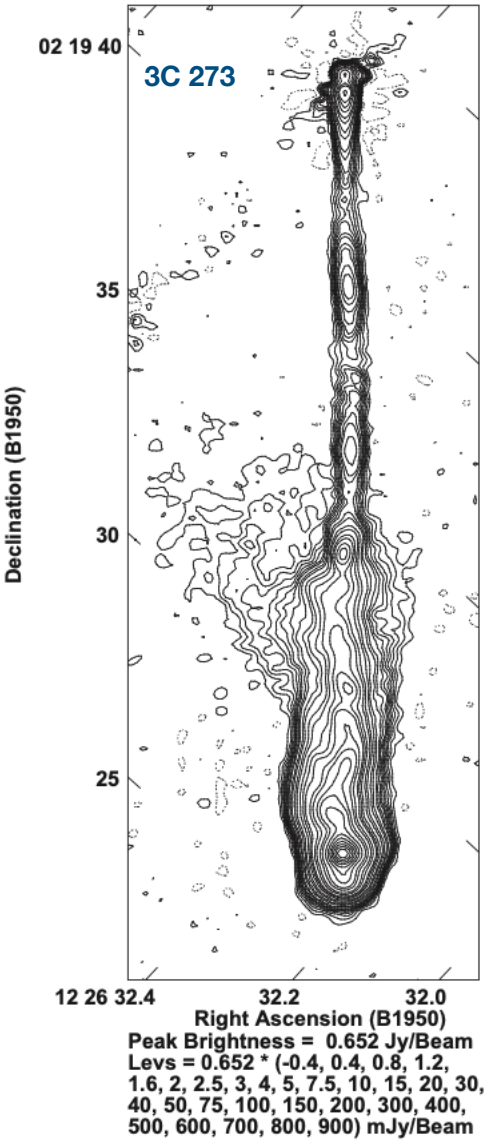


Kellermann et al.



However…

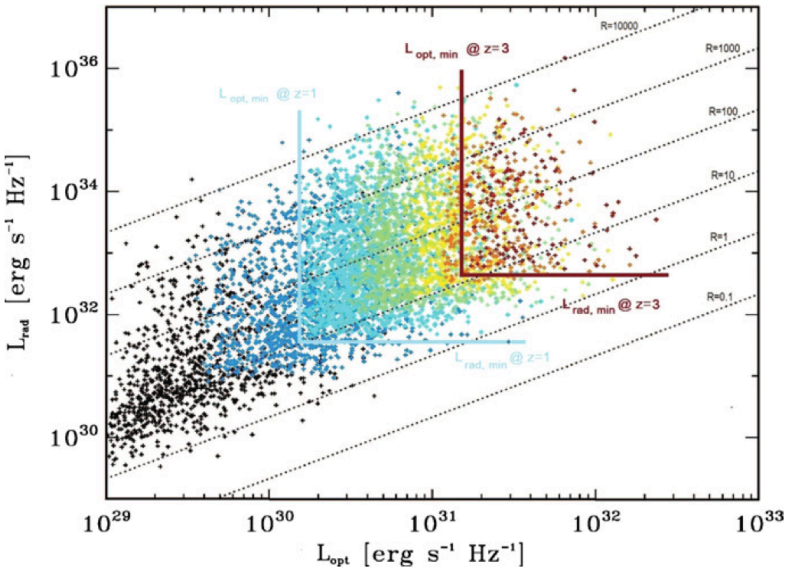
- in a sample of sources distributed over a large range of cosmological distances, one has to take into account the truncations (**flux limits!**) and correlations (**luminosity-redshift, aka the luminosity evolution**; also luminosity-luminosity) inherent in the data

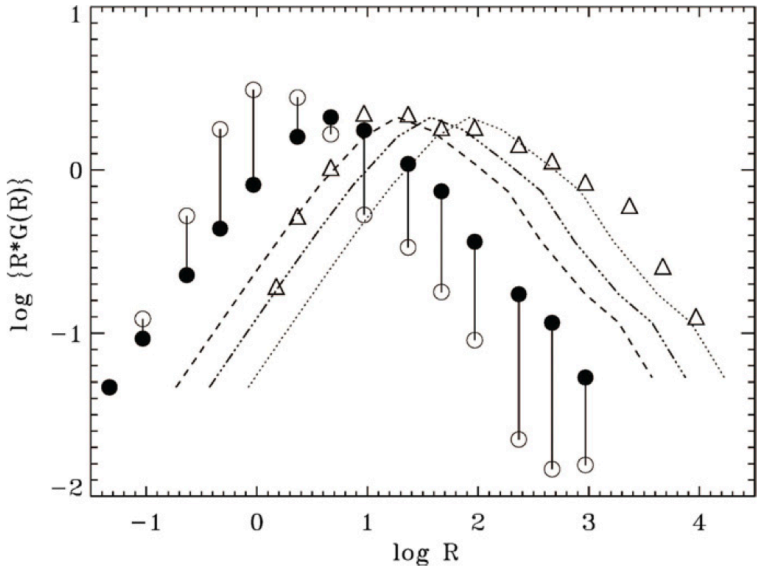
- the SDSS x FIRST quasar population exhibits **strong positive evolution with redshift in both wavebands, with somewhat greater radio evolution than optical**; also a strong positive correlation between the radio and optical luminosities

- the intrinsic distribution of the radio-loudness parameter R > 0.1 is found to be quite different from the observed one and is smooth with **no evidence of a bimodality**

$$G_R(R,z) = \int_0^\infty \Psi(L_{\rm opt},\, R\ L_{\rm opt},\, z)\, L_{\rm opt}\, dL_{\rm opt}$$
$$= \int_0^\infty \Psi\left(\frac{L_{\rm rad}}{R}, L_{\rm rad}, z\right) L_{\rm rad}\, \frac{dL_{\rm rad}}{R^2}.$$

Single, Petrosian, Stawarz & Lawrence

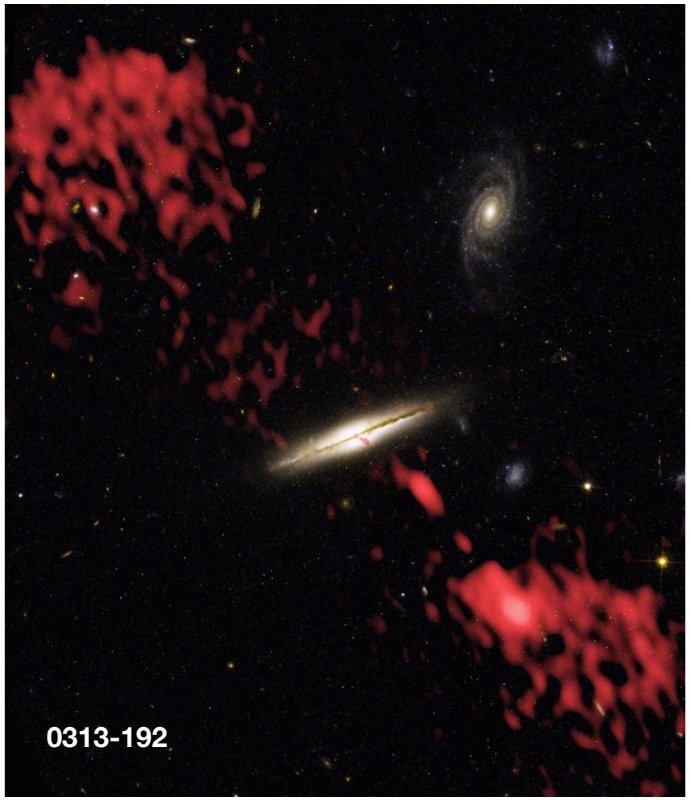


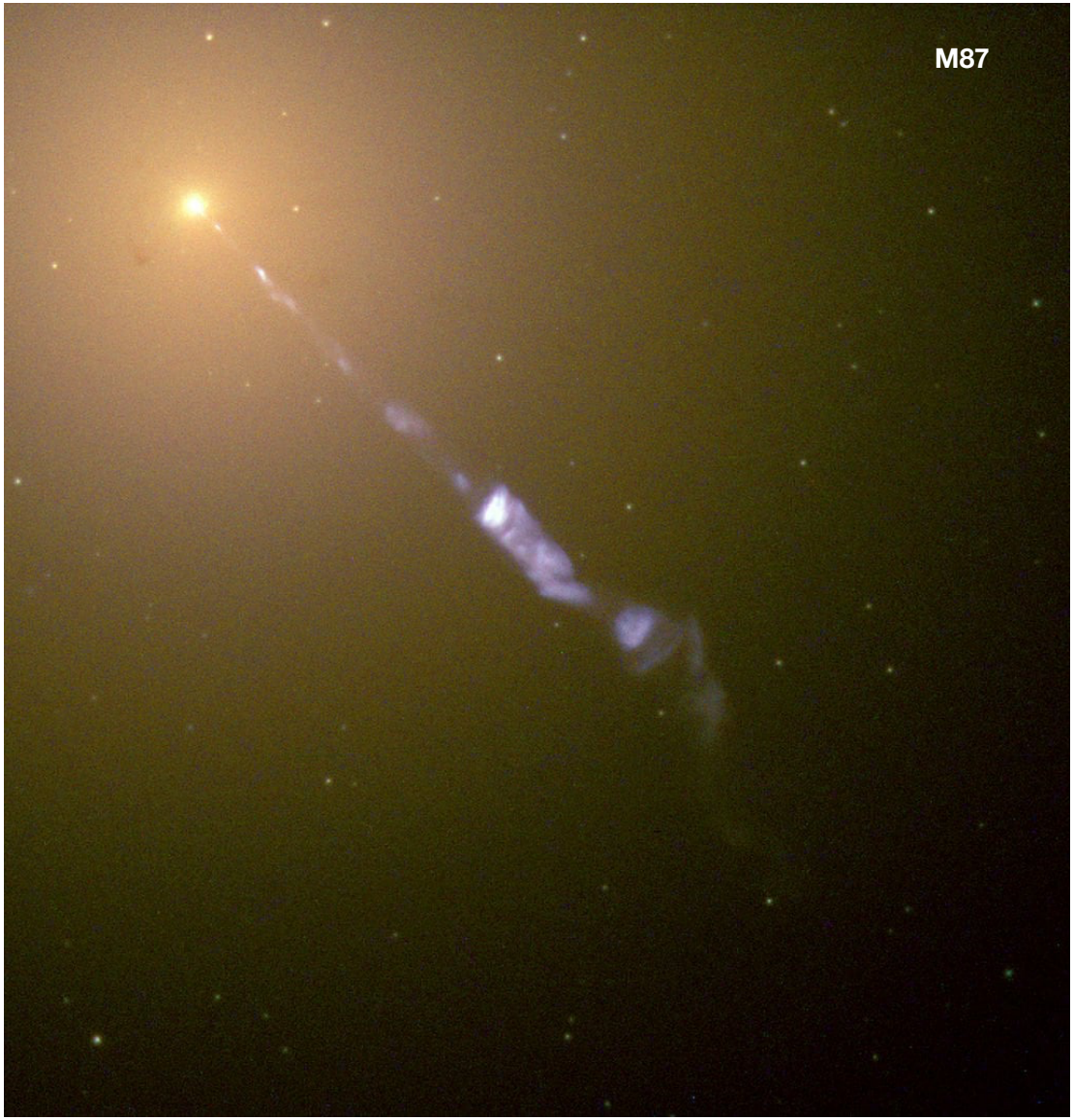


Host Galaxies

- the overwhelming majority of bright, prominent radio jets are hosted by **early-type galaxies**

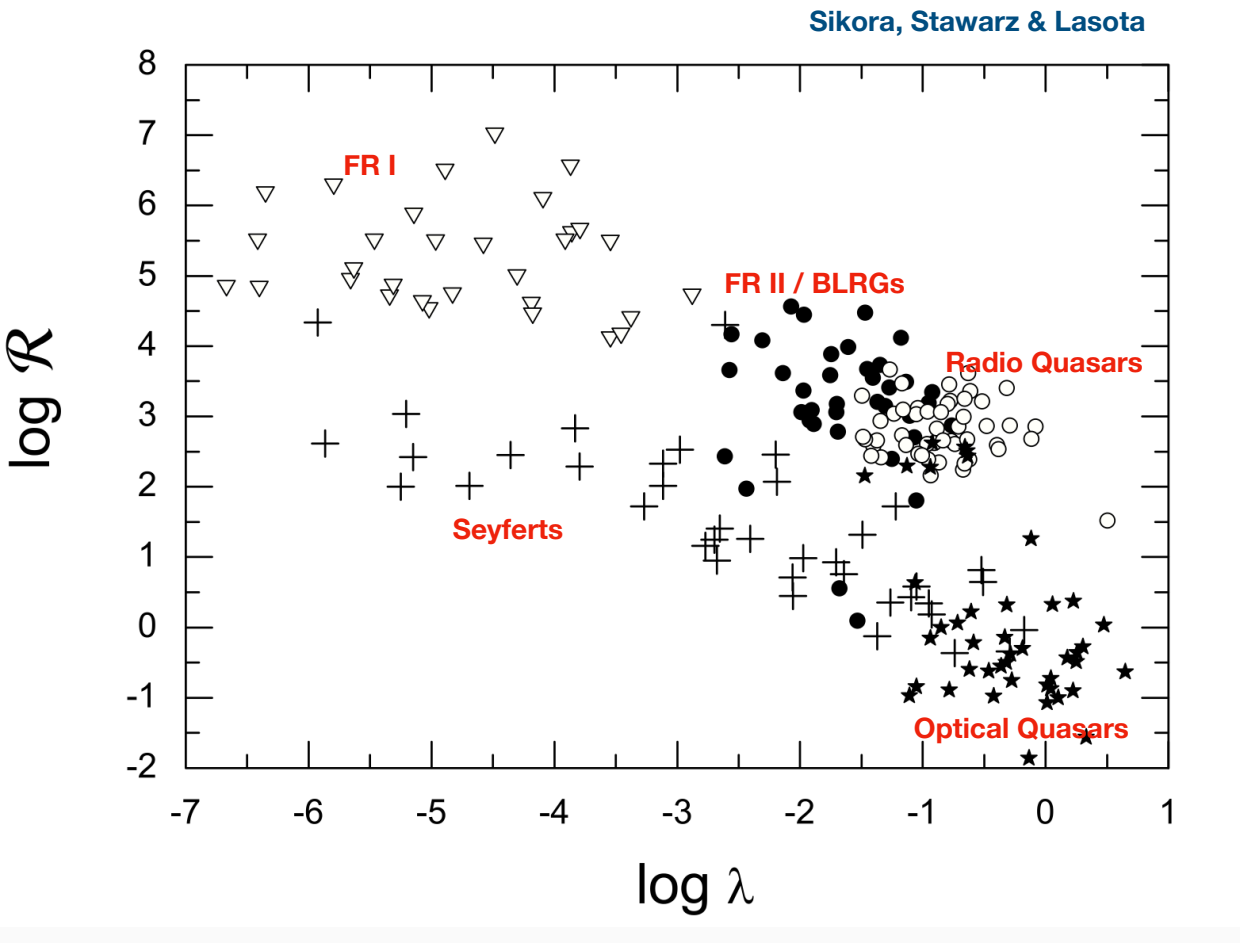
- **late-type galaxies** do host radio jets, but those typically are very low-power, short, and sub-relativistic





Morphology-related bimodality

- AGN form **two distinct and well-separated sequences** on the radio-loudness – Eddington-ratio plane, extending down from the quasar range to very low accretion rates.
- the sequences mark the real upper bounds of radio loudness of two distinct populations of AGN hosted respectively by **early-type and late-type galaxies**.
- this could suggest that central black holes in early-type galaxies have (on average) **much larger spins** than black holes in late-type galaxies



However…

- incomplete samples…
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- masses of central SMBHs often rather uncertain

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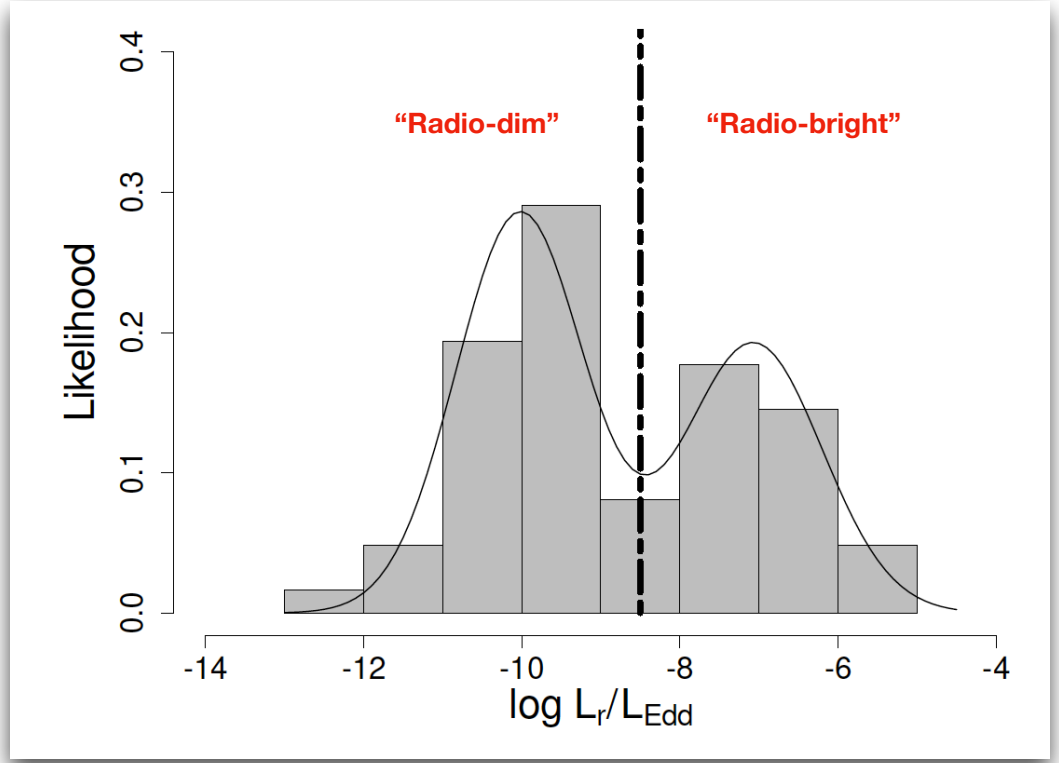
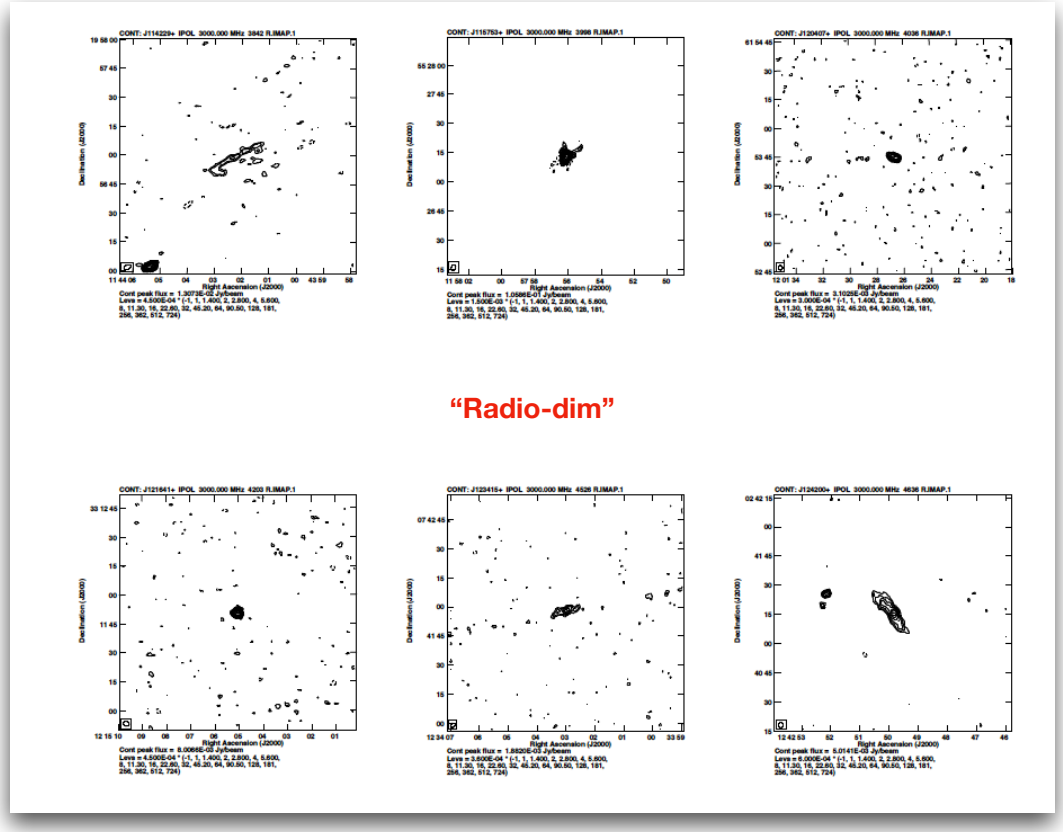
So instead…

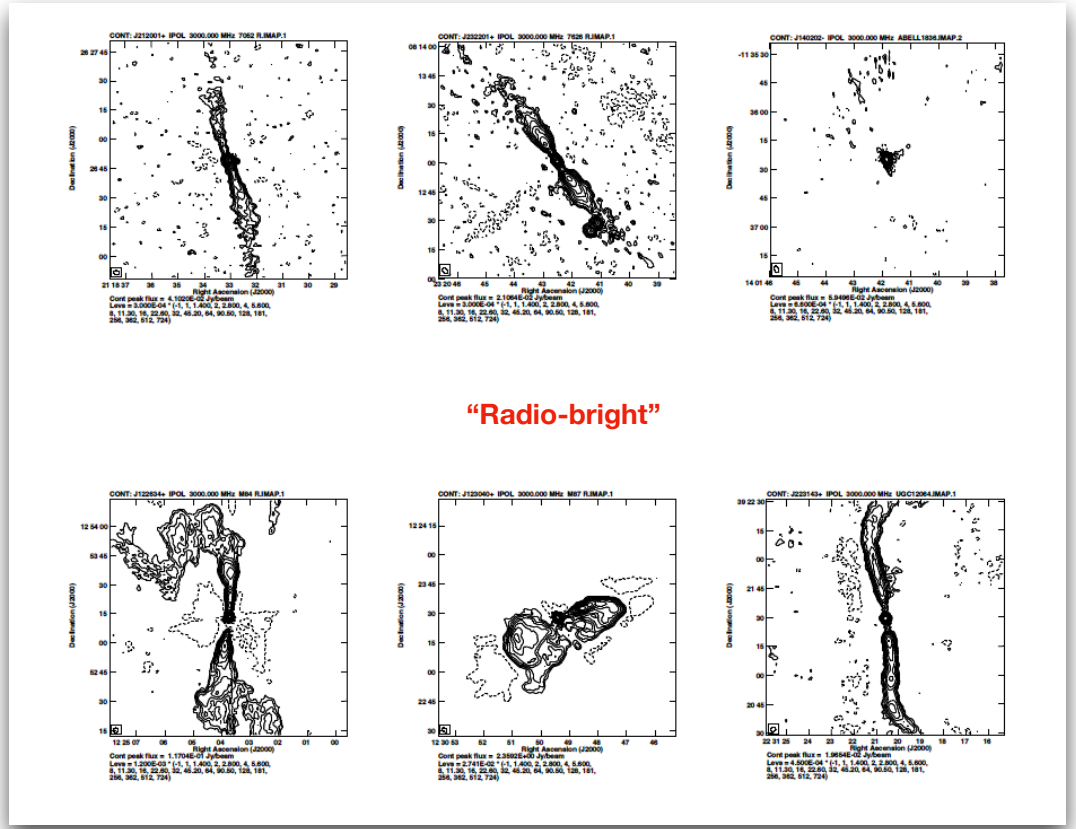
- a systematic analysis of **all nearby galaxies with dynamical measurements of SMBH masses**, and well-characterized optical and X-ray properties (bulge masses and velocity dispersion, hot halo luminosity and temperature, etc.)
- selection **regardless on the exact level of the nuclear activity**
- result: **a clear bimodality** in the Eddington-normalized radio luminosities for the early-type galaxies



Wójtowicz, Stawarz, et al.



“Radio-dim”



“Radio-bright”

Conclusions

- all galaxies display some level of the AGN activity
- jet activity is also a common property (although not a simple scaling of the nuclear accretion rate!)
- selection effects, cosmological evolution, jet intermittency, classification issues…
- a clear dependence on the host morphology
- elusive imprint of the SMBH spin distribution/evolution