ON THE RADIO LOUDNESS and THE ACCRETION MODE of LLAGN

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KEY QUESTIONS

- **WHAT DOES RADIO LOUDNESS MEAN FOR LLAGN?**
- **HOW IS IT RELATED TO ACCRETION/EJECTION**
- **WHAT ARE THE FUNDAMENTAL PARAMETERS THAT MAKE AN AGN RADIO-LOUD?**
- **CAN WE "SEE" RADIATION FROM A RADIATIVELY INEFFICIENT ACCRETION FLOW IN THE OPTICAL?**

Finding RIAFs is important

BH are thought to accrete matter in a RIAF state for most of their lifetime

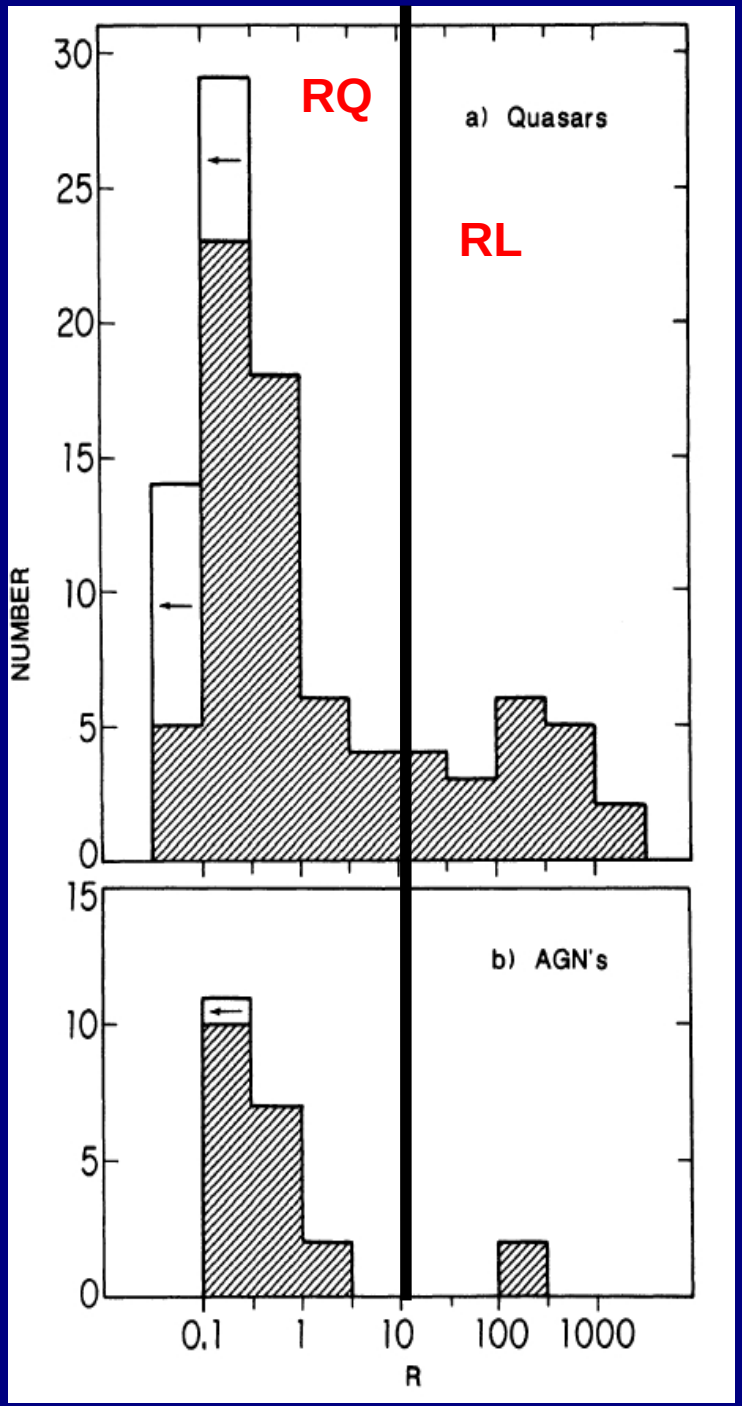
We have models for RIAFs but observations still lack behind

IR-to-UV is a crucial spectral region

We need the highest possible resolution in the IR to UV and stable PSF

WE HAVE TO USE HST

THE RL/RQ DICHOTOMY



Kellerman et al. 1989

114 PG QSO

Bimodal distribution

RL/RQ separation

$R = F_{5GHz} / F_B = 10$

Accretion disks

- "standard" Shakura-Sunyaev
  efficient radiative cooling $\varepsilon = L/\dot{M}c^2 \sim 0.1$
  geometrycally thin, optically thick disks
  $L \lesssim L_E = 1.3 \times 10^{38}\ M/M_{sun}$ erg/s

Observed in QSO and Seyfert galaxies
SED: Blue bump – IR bump (hot dust)

- RIAF (ADAF, CDAF, ADIOS, etc)
  $\dot{m} = \dot{M}c^2/L_E < \dot{m}_{crit}$, $\varepsilon \ll 0.1$
  $L/L_E \ll 1$
  geometrically thick, optically thin

SED: synchrotron peak, IC peak(s), Bremsstrahlung

Where can we find them?

XRB in quiescence?, Galactic center?, LINERS?, LLRG?, Seyferts?

ARE THERE REALLY RIAFs in LLAGN?
(and can we see them?)

e.g. Ho 1999, Ho et al. 2002

YES. LLAGN host RIAFs

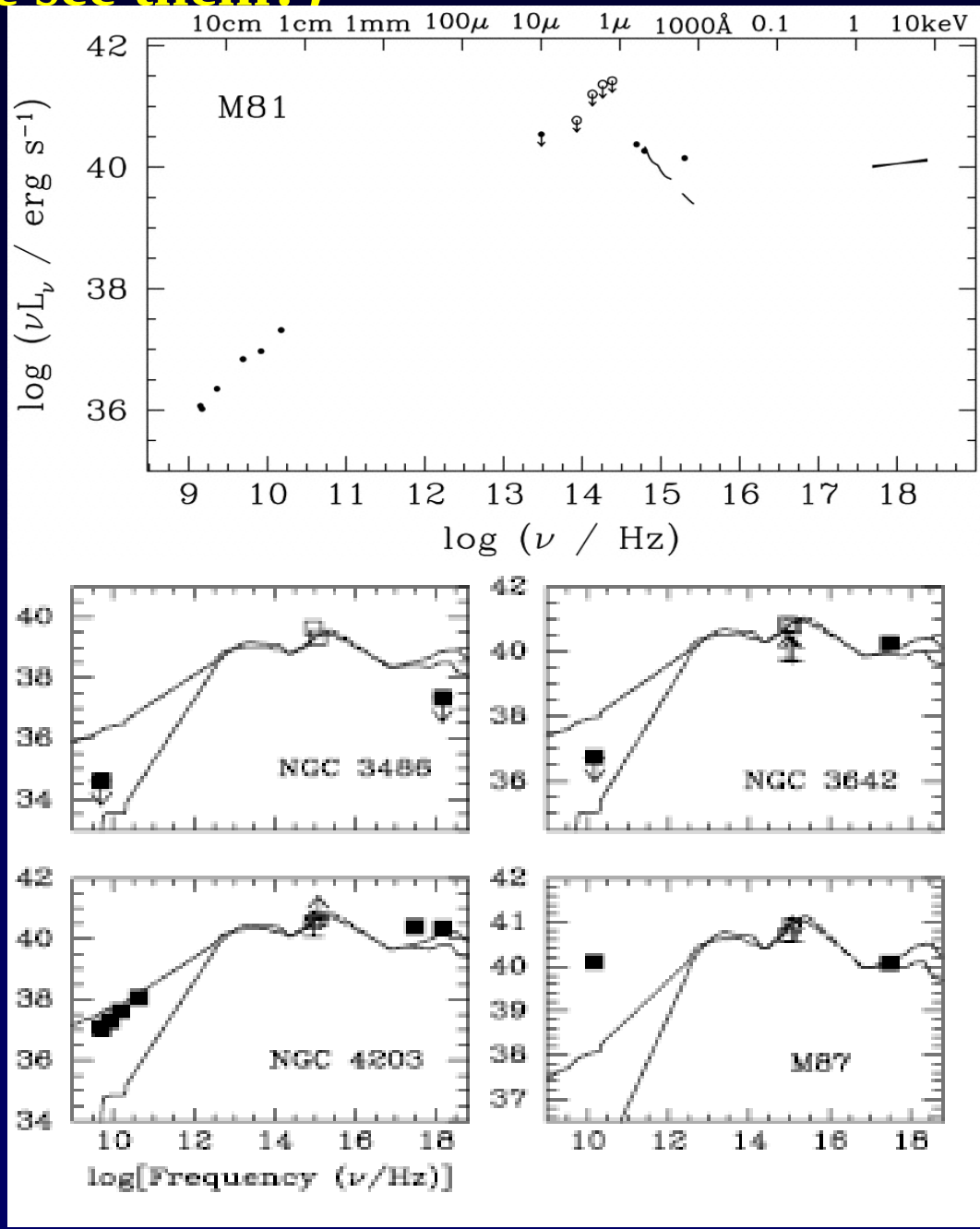
Based on L/L_{Edd} and SEDs

e.g. Maoz 2007

NO. The SED of LLAGN are similar to those of QSOs

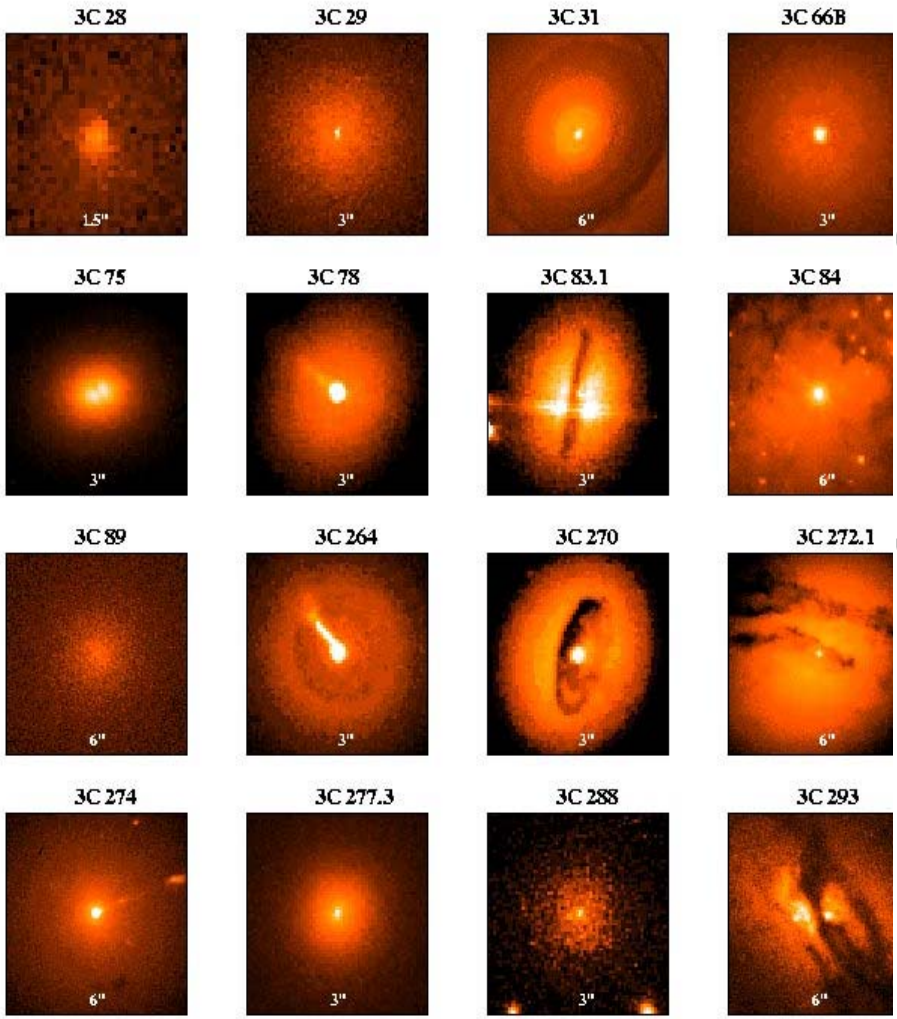
BUT

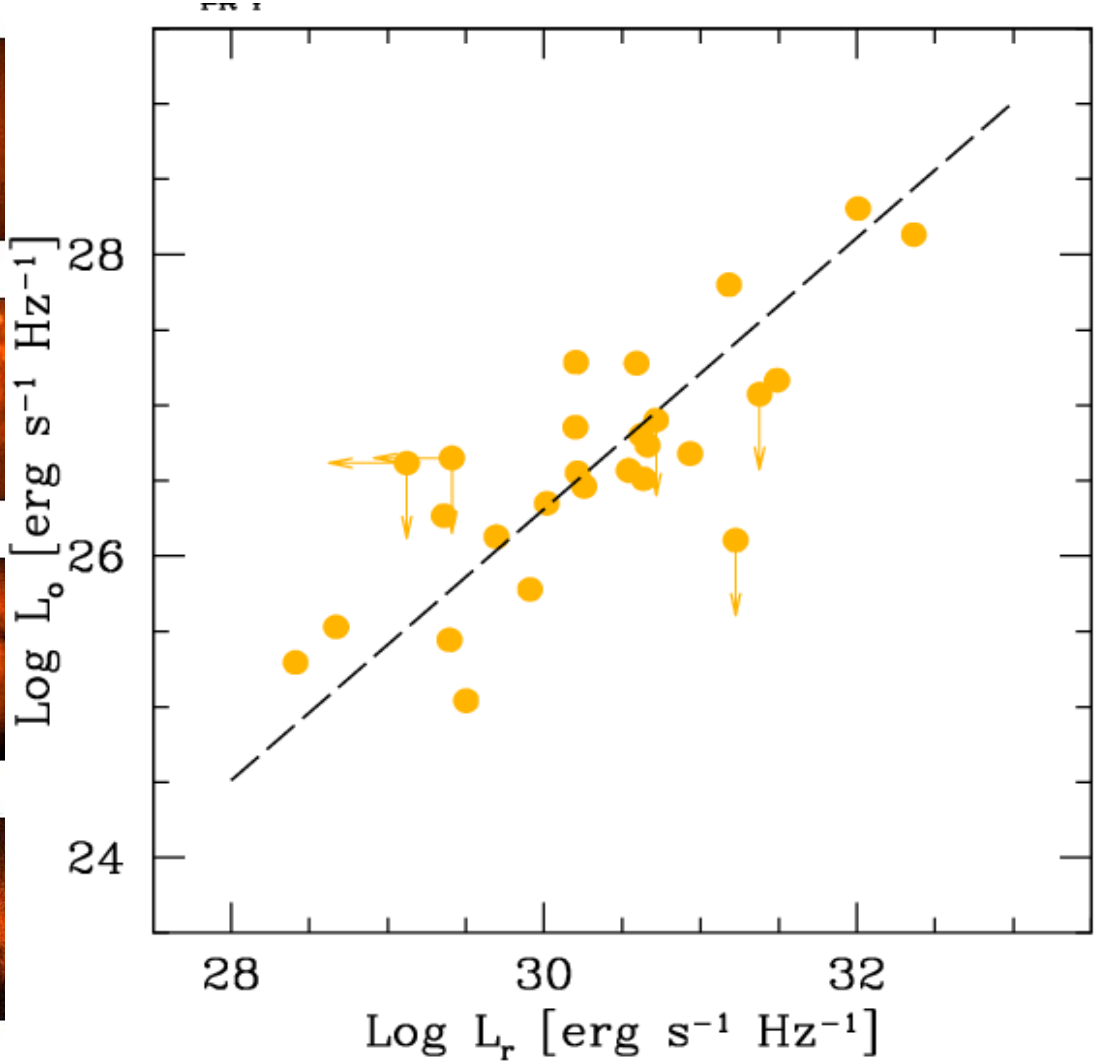
- Sparse coverage of the SED
- Non-simultaneous data
- The crucial IR-to-UV band is generally not covered by HST data
- Incorrect sample selection



THE HST VIEW of FR I radiogalaxies

Complete sample:
33 objects, 32 with HST R-band observations





The HST/WFPC2 snapshot survey of 3CR radio sources (P.I. Sparks)

Chiab, Capetti & Celotti 1999

Low luminosity radio galaxies (FRI) are unobscured

Synchrotron radiation from the jet dominates
(at all wavelengths!!)

Even if they were to host RIAFs we cannot see them

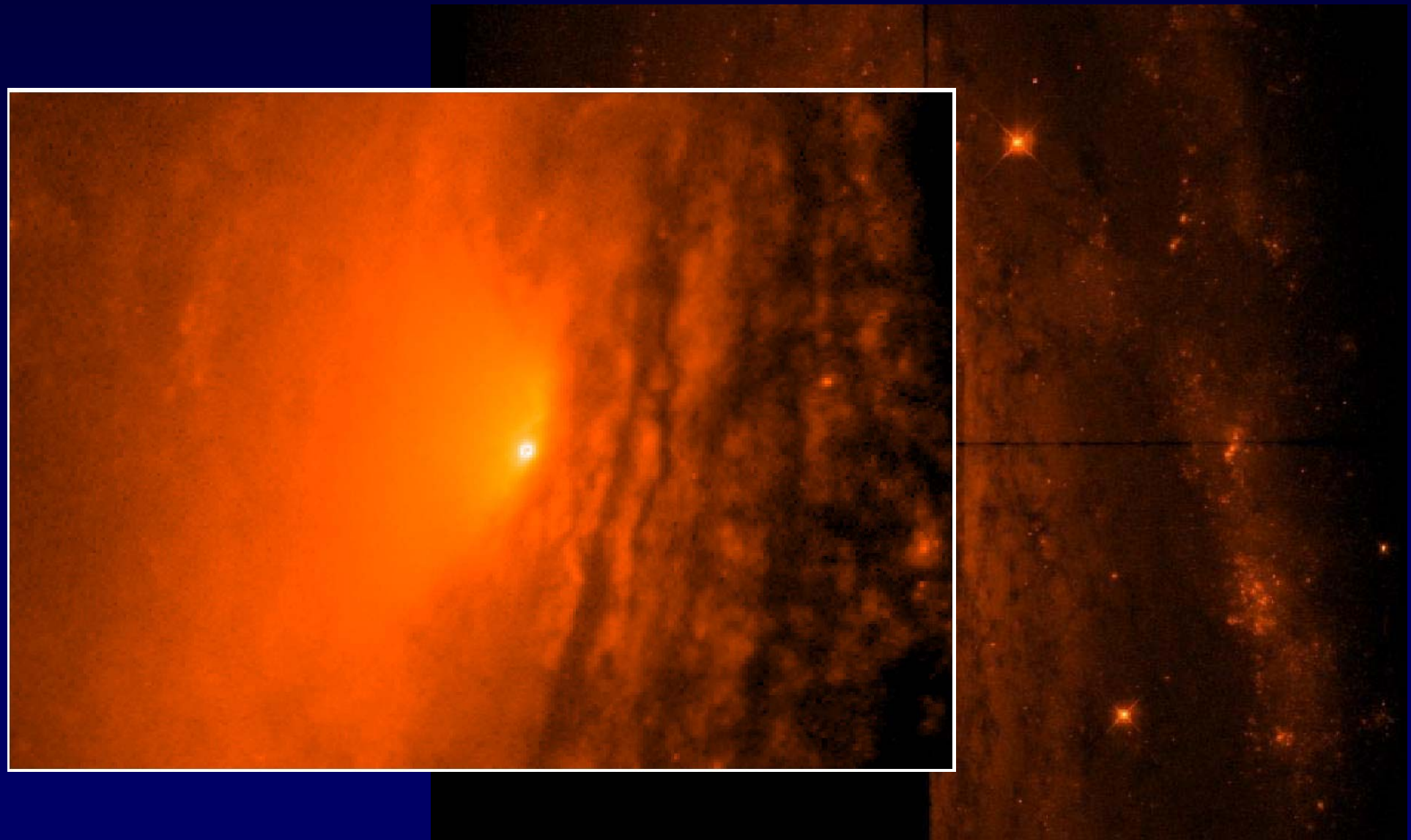
M87, M84, NGC 6251, NGC4261.... are NOT good candidates for observing RIAFs

WHAT ABOUT THE OTHER CLASSES OF LLAGN IN THE LOCAL UNIVERSE?

25 Seyfert 1

from Ho & Peng 2001
Palomar sample (d_{med} = 20 Mpc)
CfA sample (d_{med} = 80 Mpc)

NGC 5033 - HST WFPC2 - V band



21 LINERs

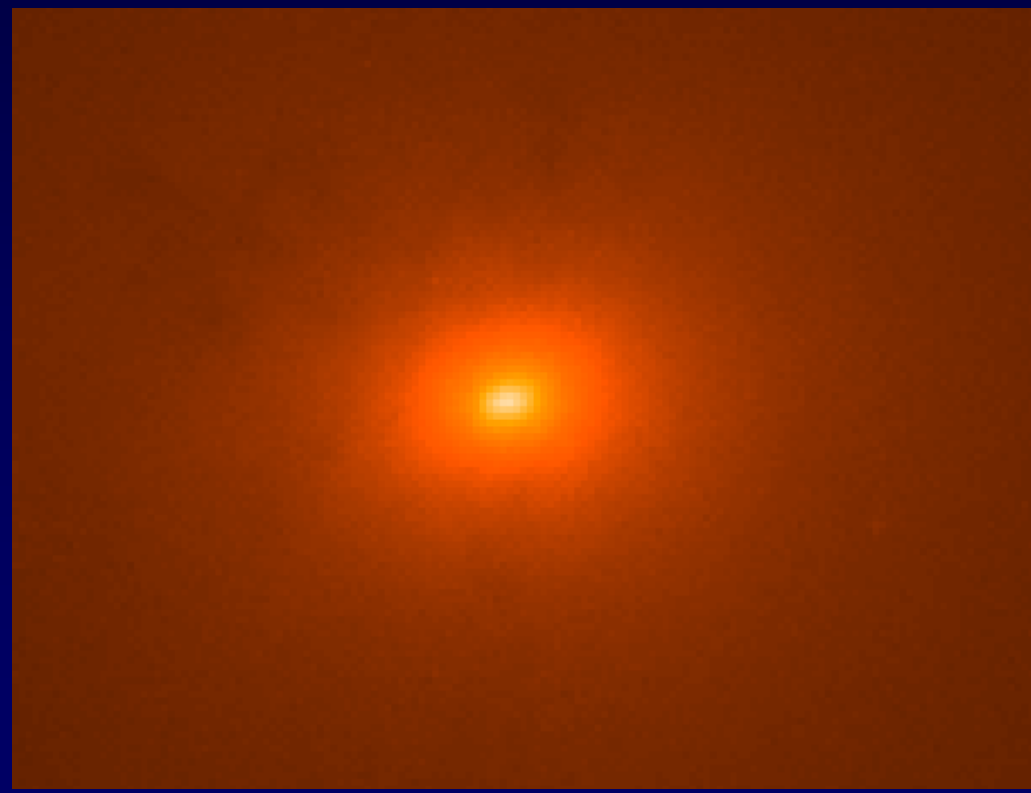
d < 19 Mpc from the Palomar sample (Ho et al 1997)

Unresolved nuclei in 40% of the objects

NGC 4278 - HST WFPC2- I band

15”

NGC 4589 - HST WFPC2- I band



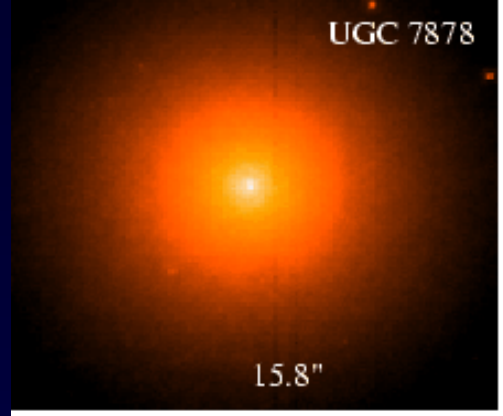
15”

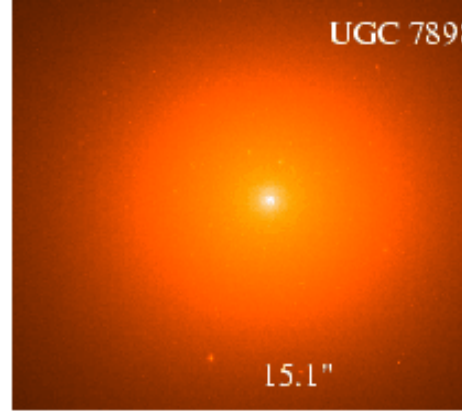
51 Nearby early-type (E+SO)
radio emission > 1mJy at 5Ghz
most are LINER or Seyfert

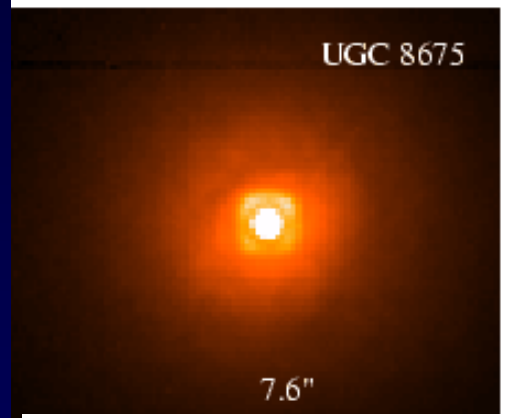
Core-galaxies
vs
Power-law galaxies
Balmaverde & Capetti 2005

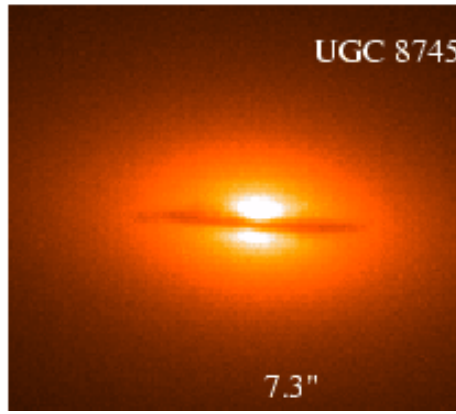
5 3C Broad line radio galaxies
z < 0.3

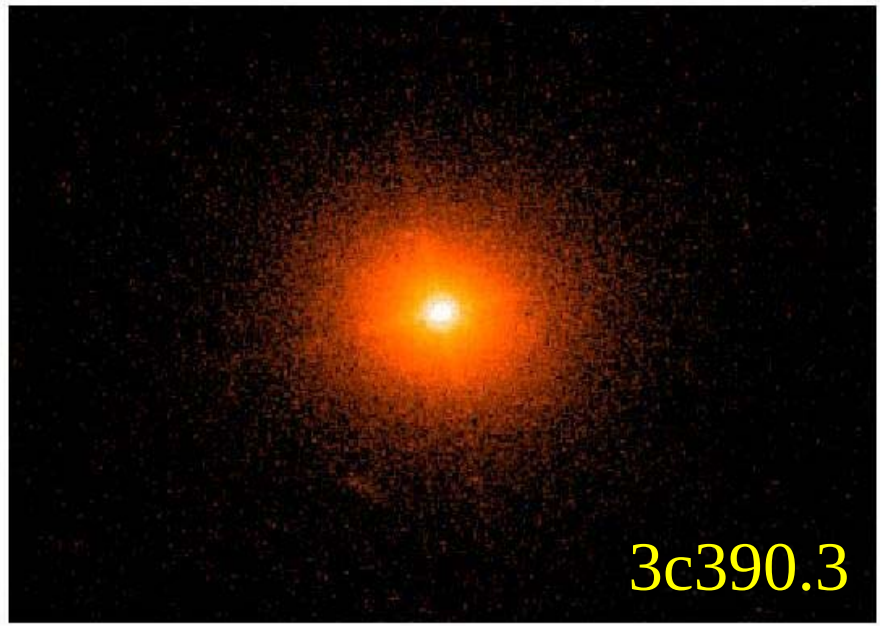
Chiab, Capetti & Celotti 2000











How can we find RIAFs?

NUCLEAR Radio Loudness:

$R = L_{radio,\ 5GHz} / L_o$

BH mass estimate:
gas kinematics, stellar kinematics, rev. mapping or M-σ relation

Optical Eddington ratio

L_o / L_{Edd}

$L_{Edd} = 1.3 \times 10^{38} (M_{BH}/M_\odot)$ erg s^{-1}

DIAGNOSTIC PLANE

ACCRETION EFFICIENCY VS. RADIO LOUDNESS (jet/disk)

SY1 NUCLEI ARE NOT RADIO-LOUD

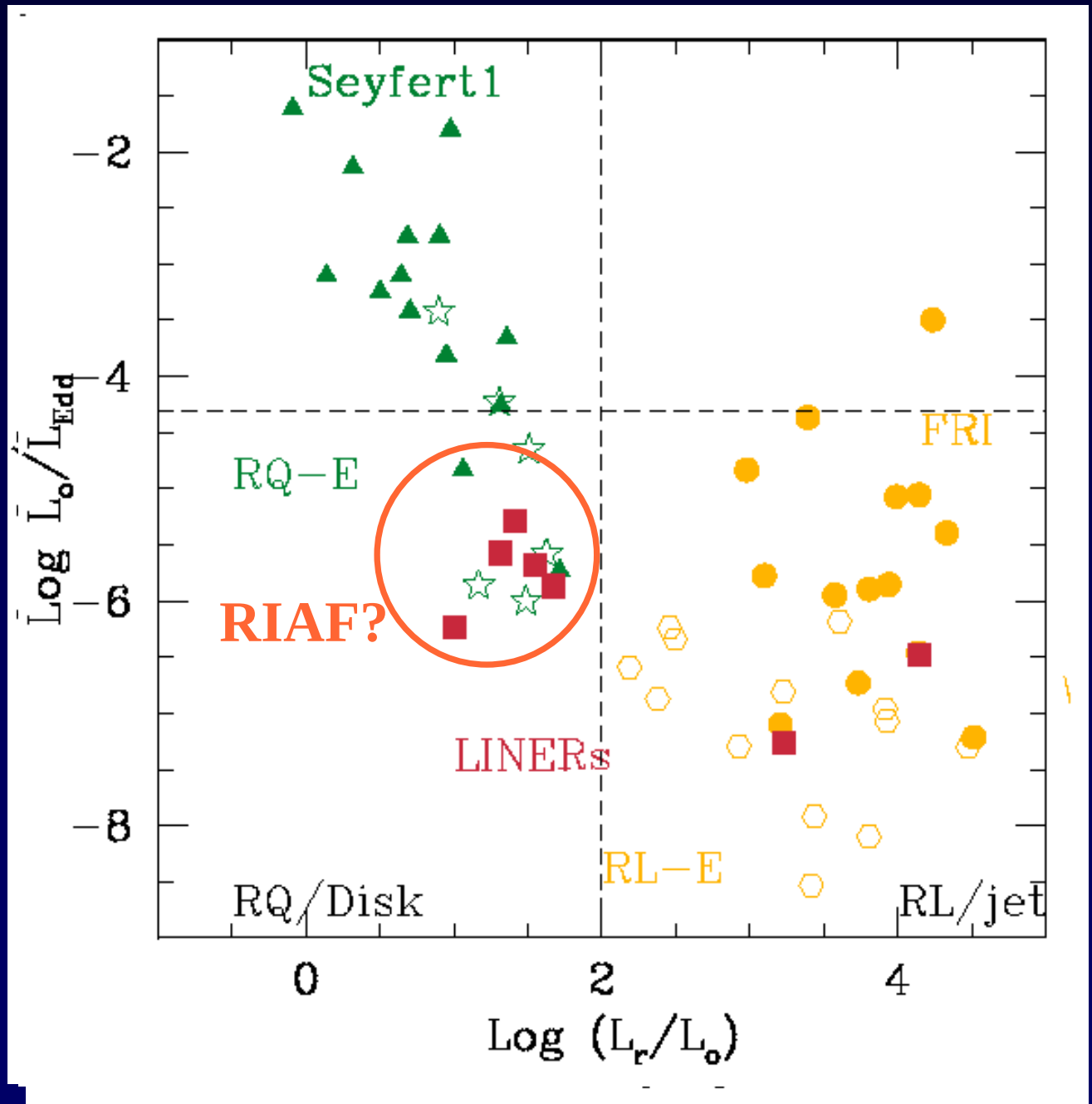
Core galaxies – RL

P-L galaxies - RQ

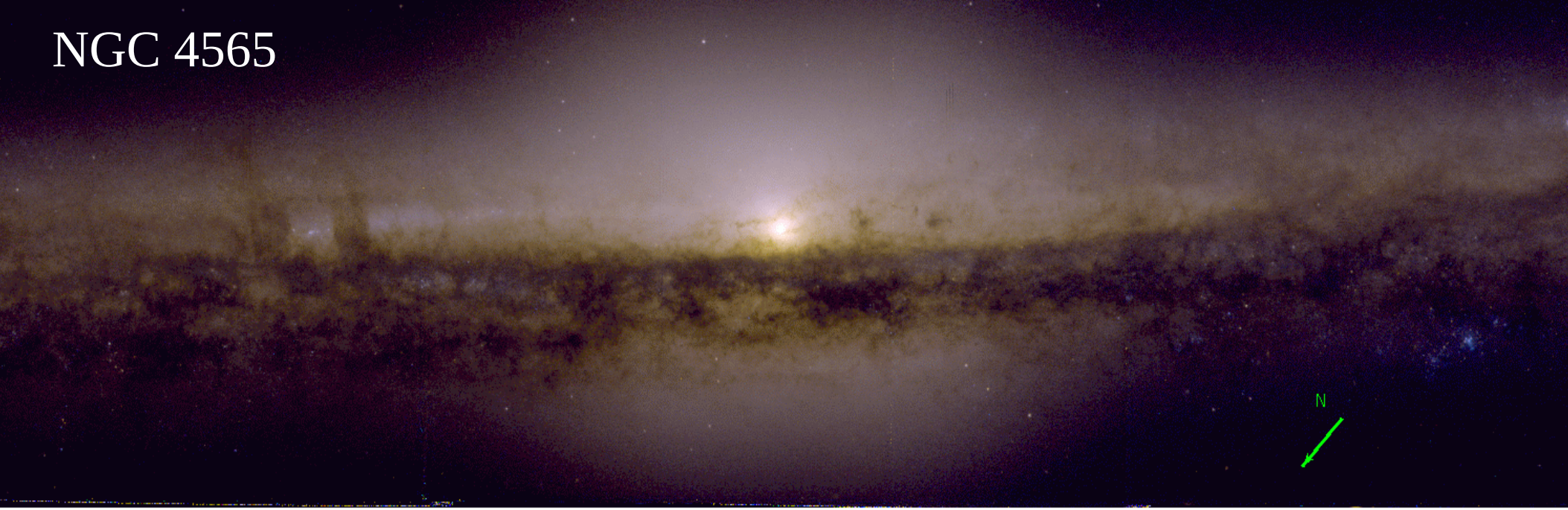
Capetti & Balmaverde 06

The nuclear radio loudness traces the emission process

Chiab, Capetti & Macchetto 2005



NGC 4565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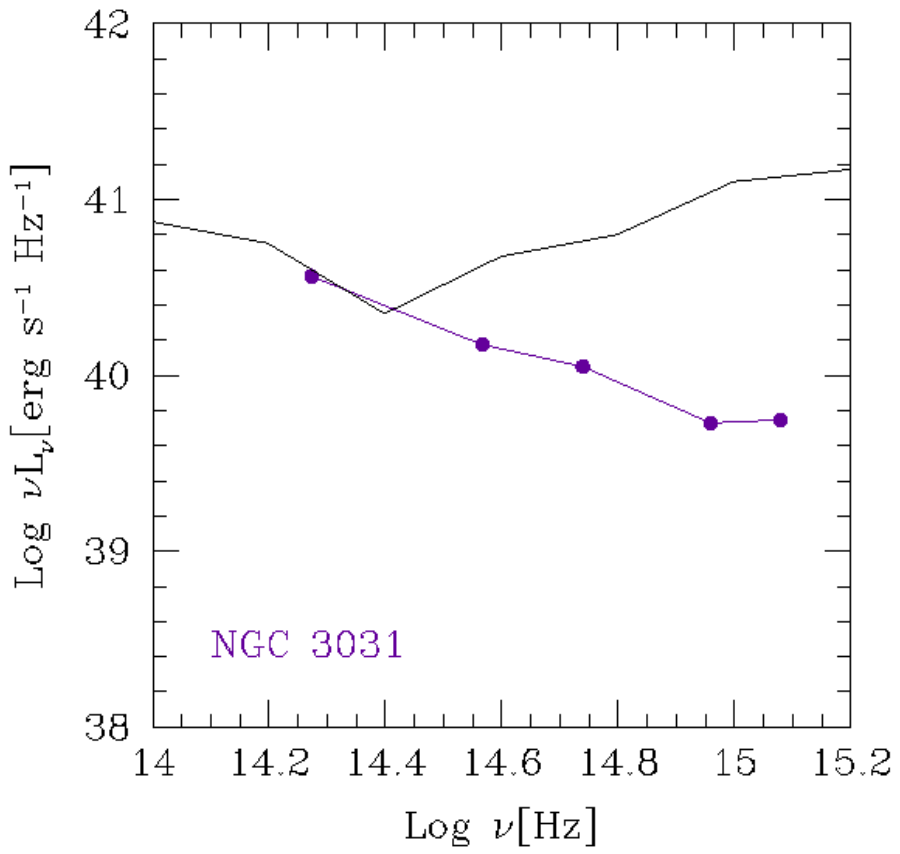
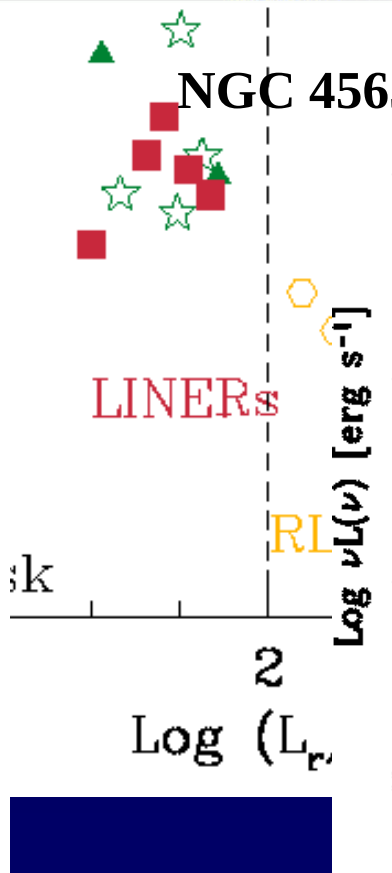
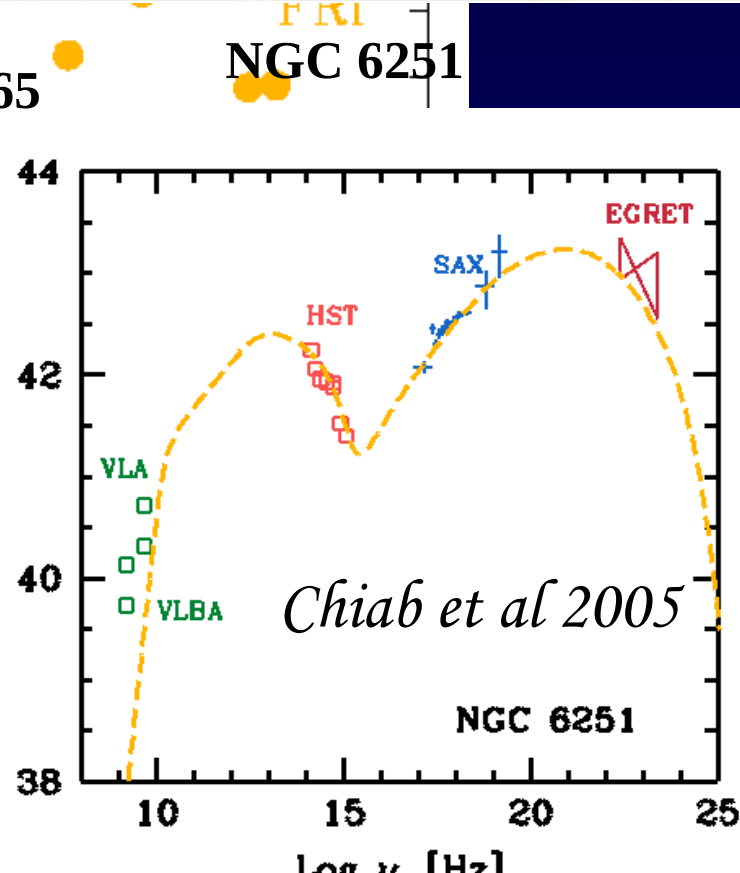

42
41
40
39
38
14
14.2
14.4
14.6
14.8
15
15.2
Log νL_ν[erg s^{-1} Hz^{-1}]
Log ν[Hz]
NGC 3031

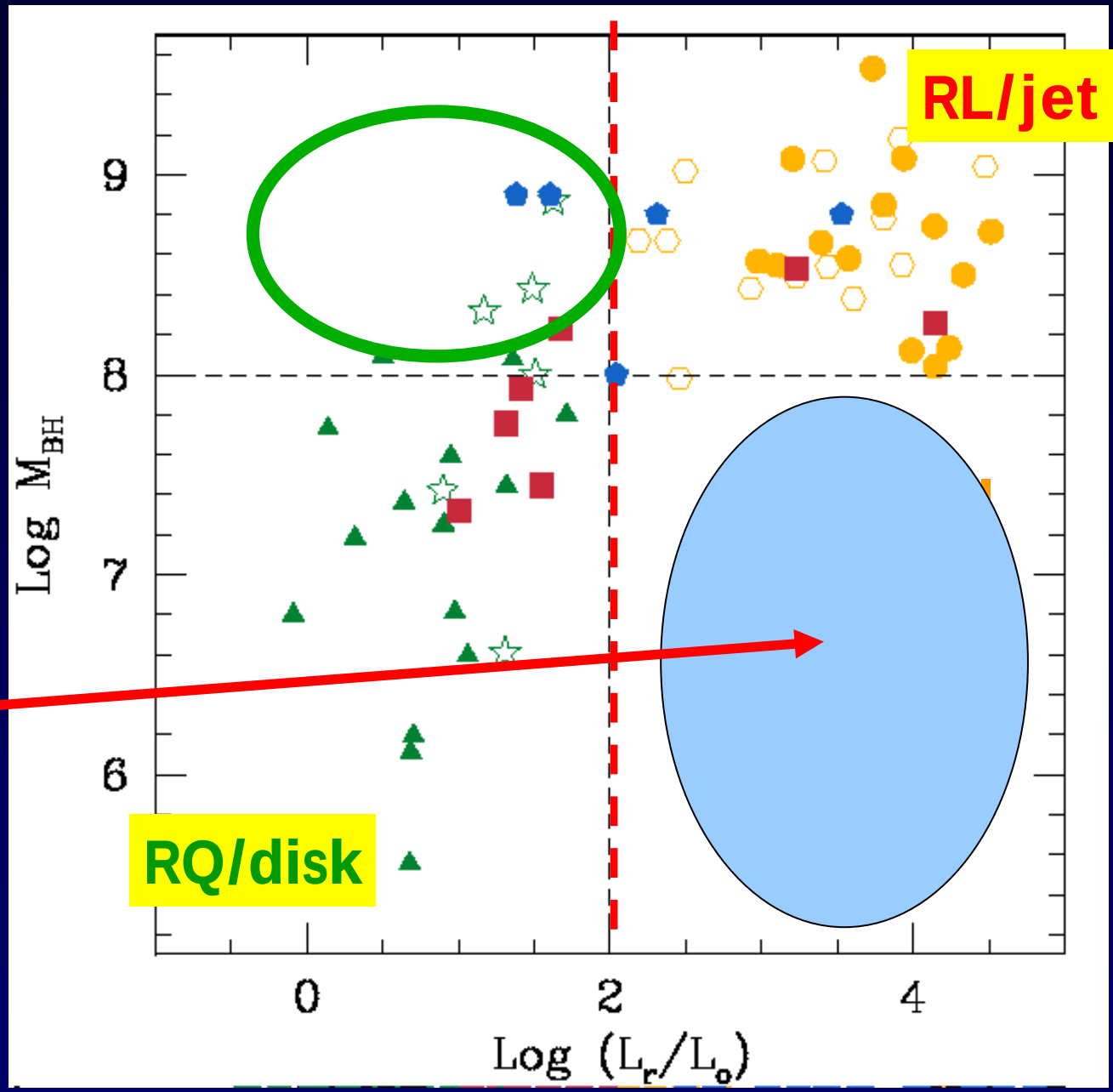

NGC 4565
LINERs
RL
sk
2
Log (L
Log $\nu L(\nu)$ [erg s^{-1}]


NGC 6251
44
42
40
38
10
15
20
25
Log ν [Hz]
EGRET
SAX
HST
VLA
VLBA
Chiab et al 2005
NGC 6251

BLACK HOLE MASS VS. RADIO LOUDNESS

RL AGNs have $M_{BH} > 10^8$

Why there are no objects here?

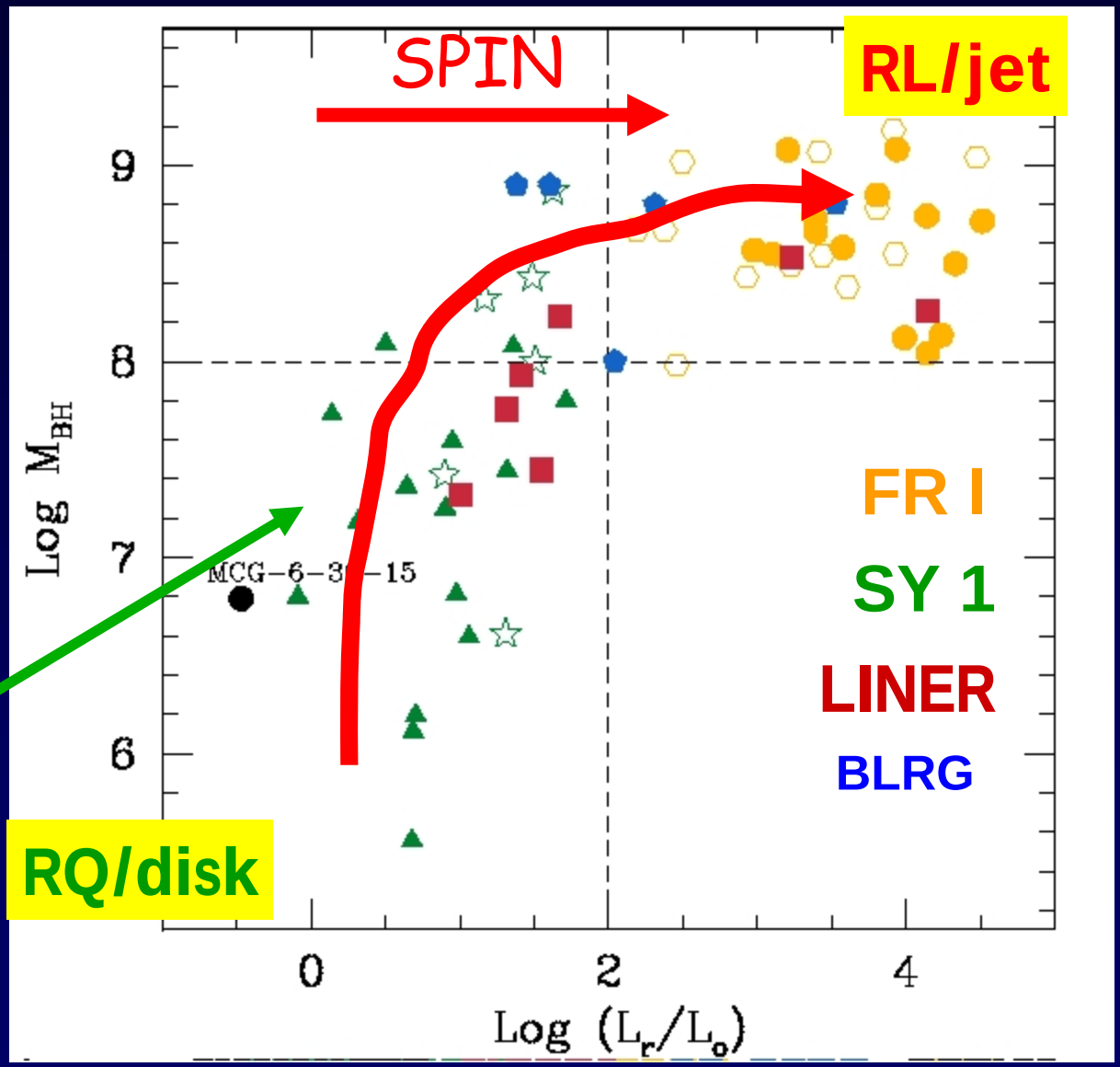


BLACK HOLE MASS VS. RADIO LOUDNESS

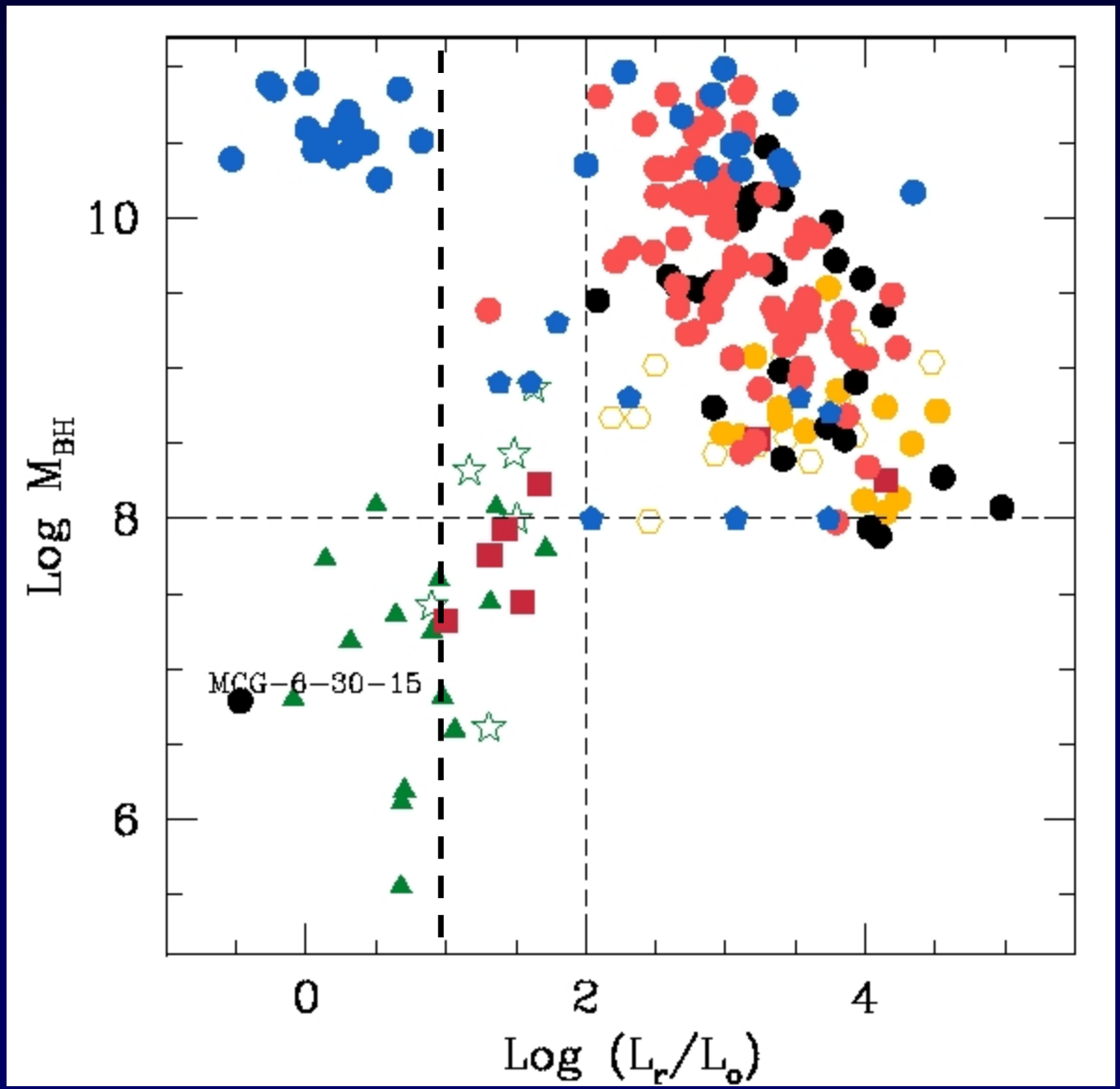
MCG-6-30-15
$M_{BH} < 10^7$

(McHardy et al. 2005)

Even if the BH is spinning, these objects are RQ



BLACK HOLE MASSES IN QSO



Virial BH masses of QSOs from

Woo & Urry 2002

(Gu et al 2001, Oshlack et al 2002, McIntosh et al 1999)

BUT:

Applying the correction for radiation pressure on the NLR

Marconi et al 2007

$$M_{BH}=6.13(V_{H\beta}/1000)^2(L_{5100}/10^{44})^{0.5} + 7.72\,(L_{5100}/10^{44})$$

Chiaberge et al. 2008

A REVISED SUPER-UNIFICATION PARADIGM

	Fundamental parameters		
	M_{BH}	Acc. rate/eff.	spin
LINERS (RQ)	L	L	L/H
LINERS (RL)	H	L	H
Seyferts	L/H	H	H/L
FR I radiogalaxies	H	L	H
FR II radio galaxies	H	H	H
Radio QUIET QSO	H	H	L
Radio LOUD QSO	H	H	H

CONCLUSIONS

1. **FRI RADIO GALAXIES' NUCLEI ARE JET DOMINATED**
IF THEY HOST A RIAF, WE CAN'T DETECT IT

2. **WE SHOULD SEARCH FOR RIAFs AMONG LLAGN WITH RADIO QUIET NUCLEI (SEYFERT AND LINERS)**
IN HOW MANY OBJECTS CAN WE DETECT THEM? NOT MANY

3. **THE DATA IN THE HST ARCHIVE ARE NOT SUFFICIENT TO TELL US WHAT THE NUCLEI ARE**
IMPORTANT BANDS ARE MISSING (IR AND UV)
DATA ARE NOT SIMULTANEOUS

4. **The BH mass must be somehow related to the RL/RQ dichotomy for ALL AGNs** *(see e.g. Gopal-Krishna et al. 2008)*