EXPLORING THE TRIGGERING OF RADIO-INTERMEDIATE HERGS

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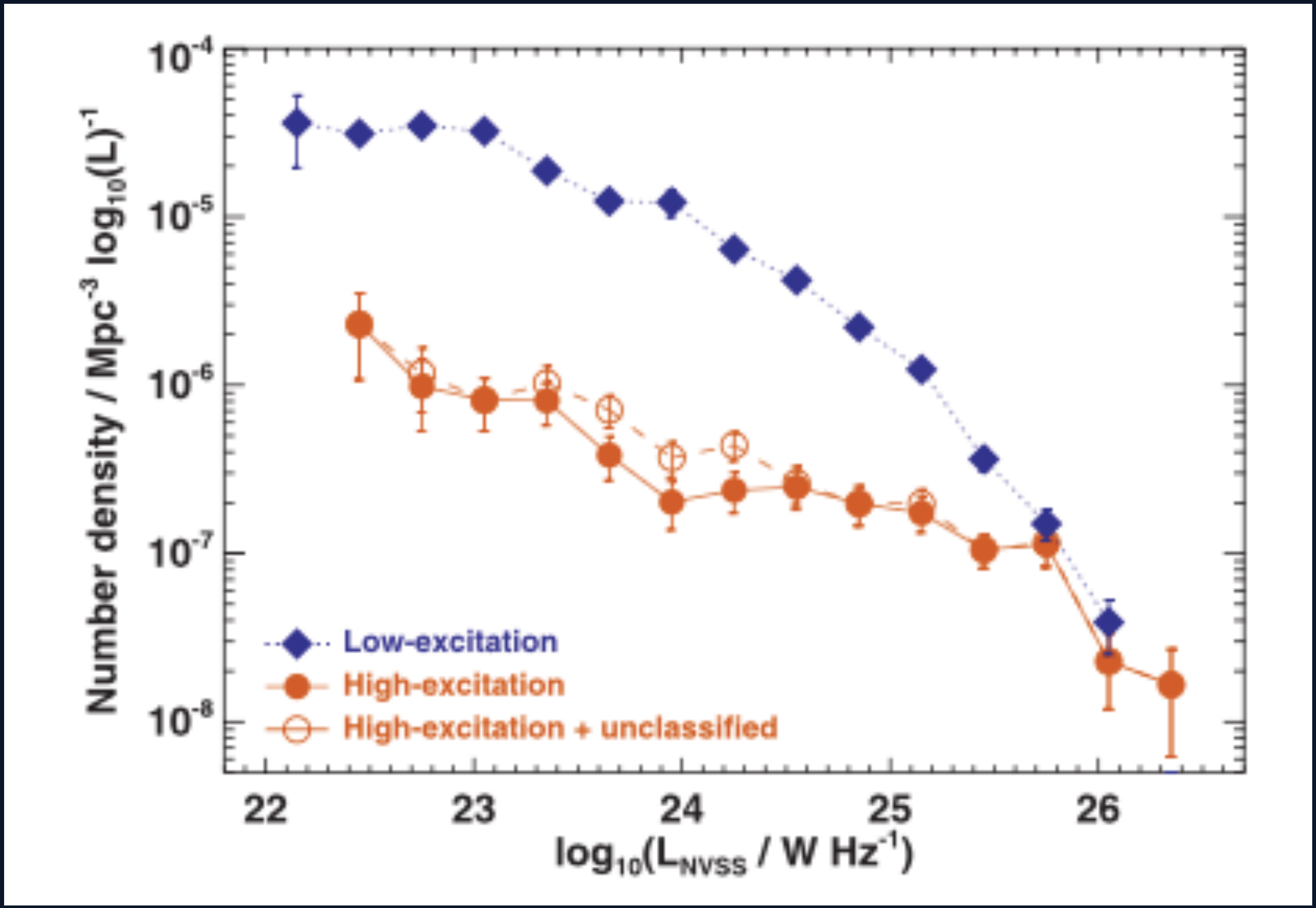
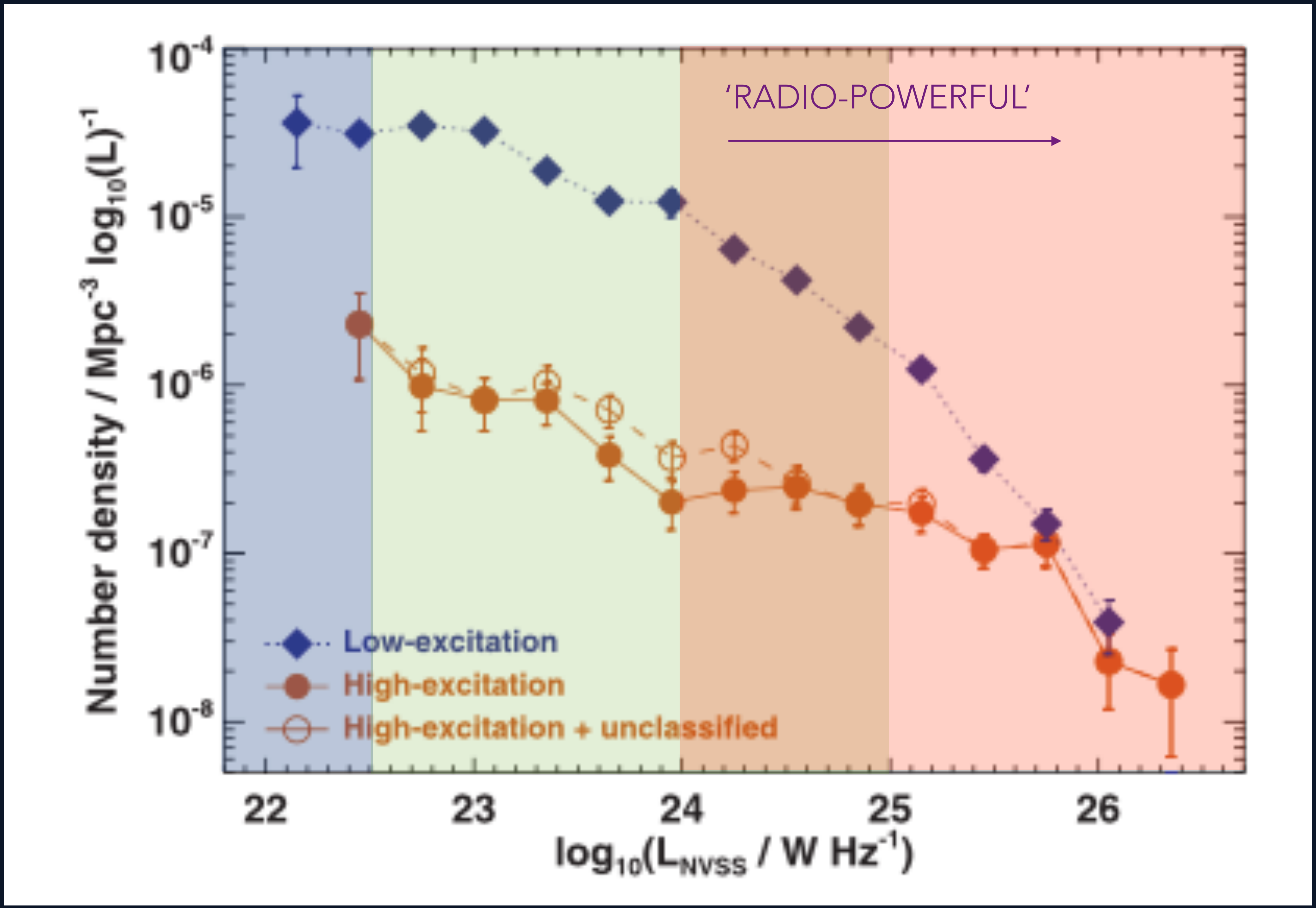
LOCAL RADIO LUMINOSITY FUNCTION



Best & Heckman 2012

LOCAL RADIO LUMINOSITY FUNCTION

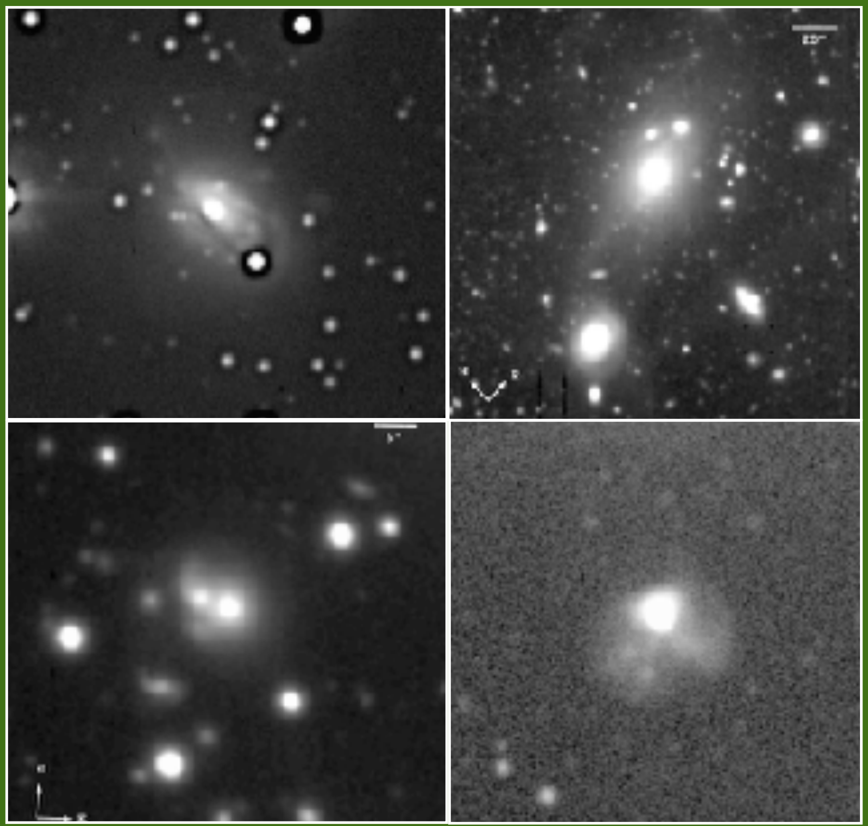


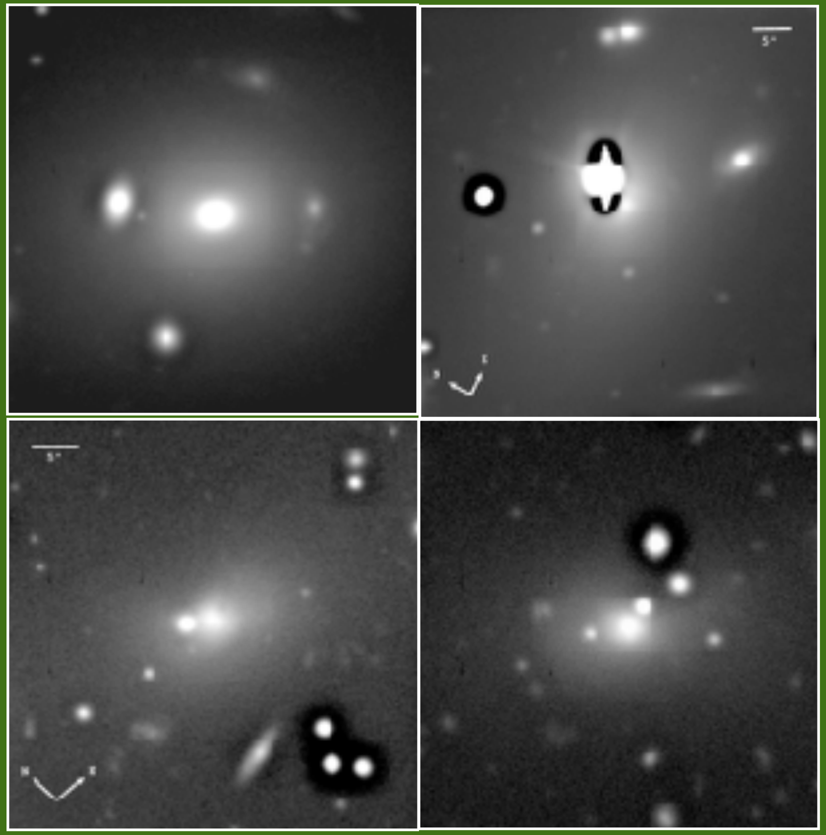
Best & Heckman 2012

RADIO-POWERFUL AGNs

HIGH-EXCITATION RADIO GALAXIES (HERGs)

- Clear tidal features are common (in 94%)
- Dense, group-like environments
- **MERGERS** are dominant triggering mechanism





LOW-EXCITATION RADIO GALAXIES (LERGs)

- Clear tidal features are rarer (in 27%)
- Very dense, cluster-like environments
- Dominant triggering **NOT BY MERGERS**

Ramos Almeida et al. 2011, 2012, 2013

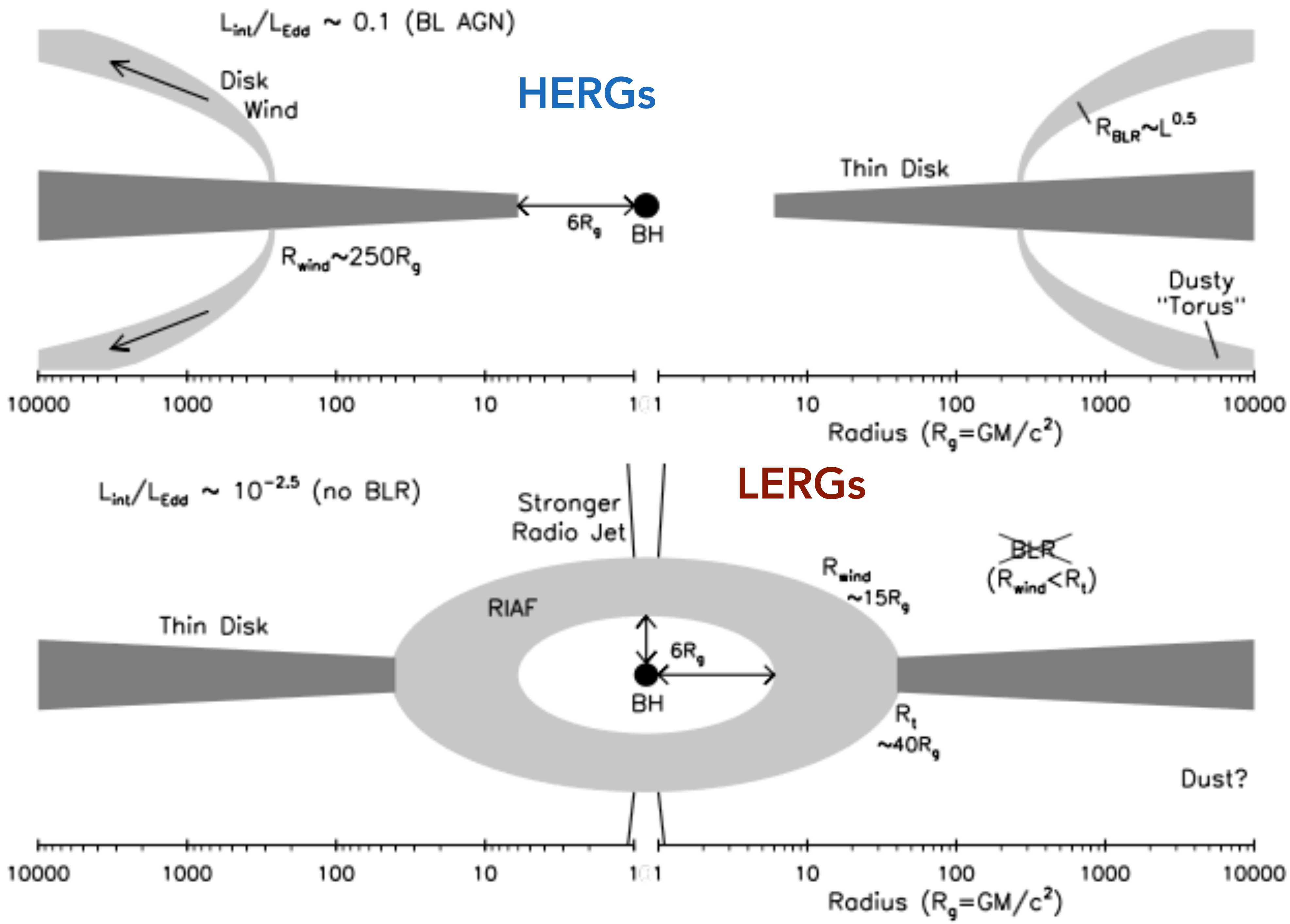
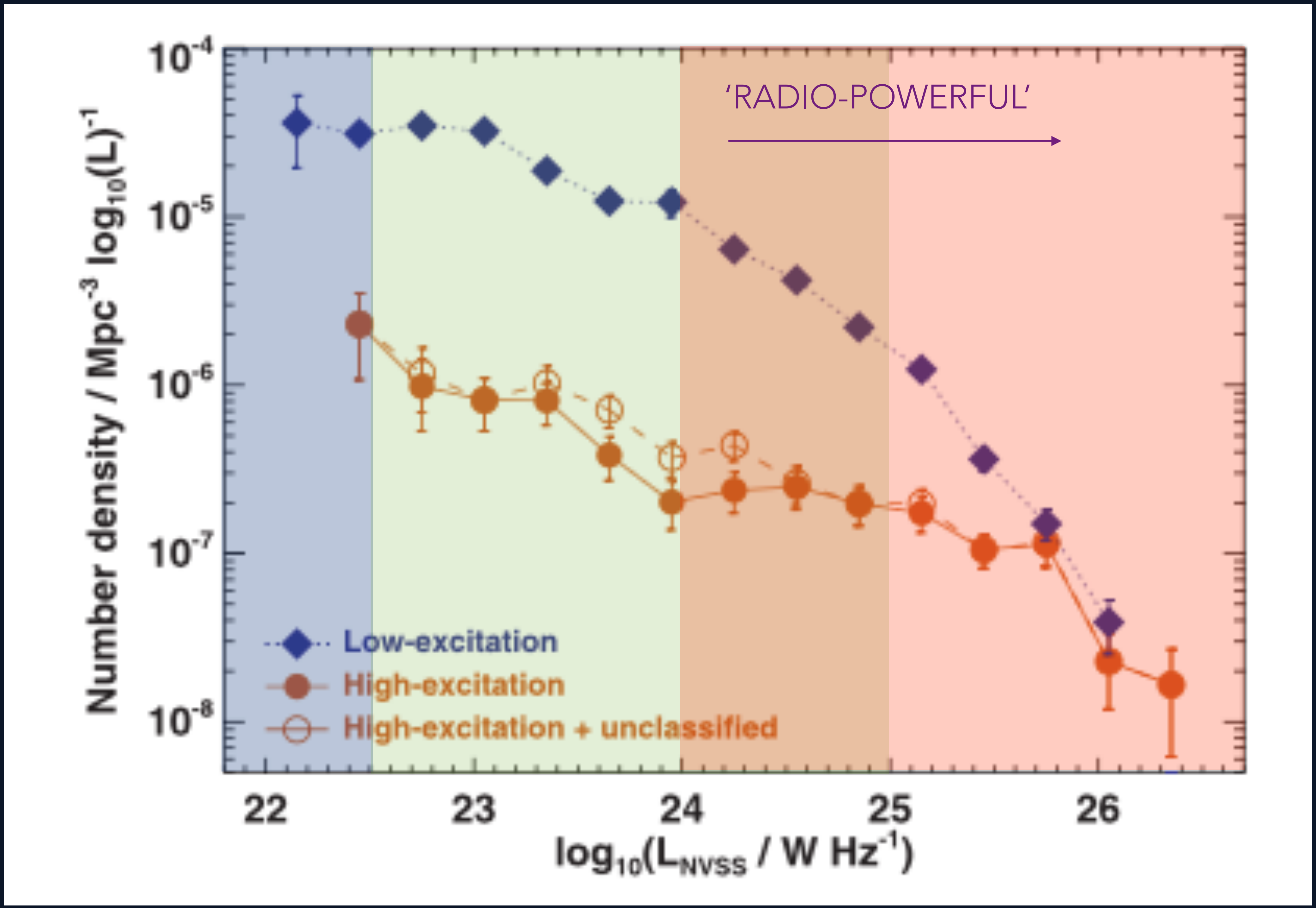


FIG. 9.— A schematic model showing the changes in the accretion disk from a broad-line AGN with high accretion rate ($L_{int}/L_{Edd} \sim 0.1$) to a narrow-line or lineless AGN with low accretion rate ($L_{int}/L_{Edd} \sim 0.003$). The x axis shows the radial distance from the black hole in units of GM/c^2. The y axis is qualitative only. At $L_{int}/L_{Edd} \lesssim 0.01$, the disk wind falls inside the RIAF. As a result there are no broad emission lines, the hot dust signature becomes very different, and the radio jet becomes stronger.

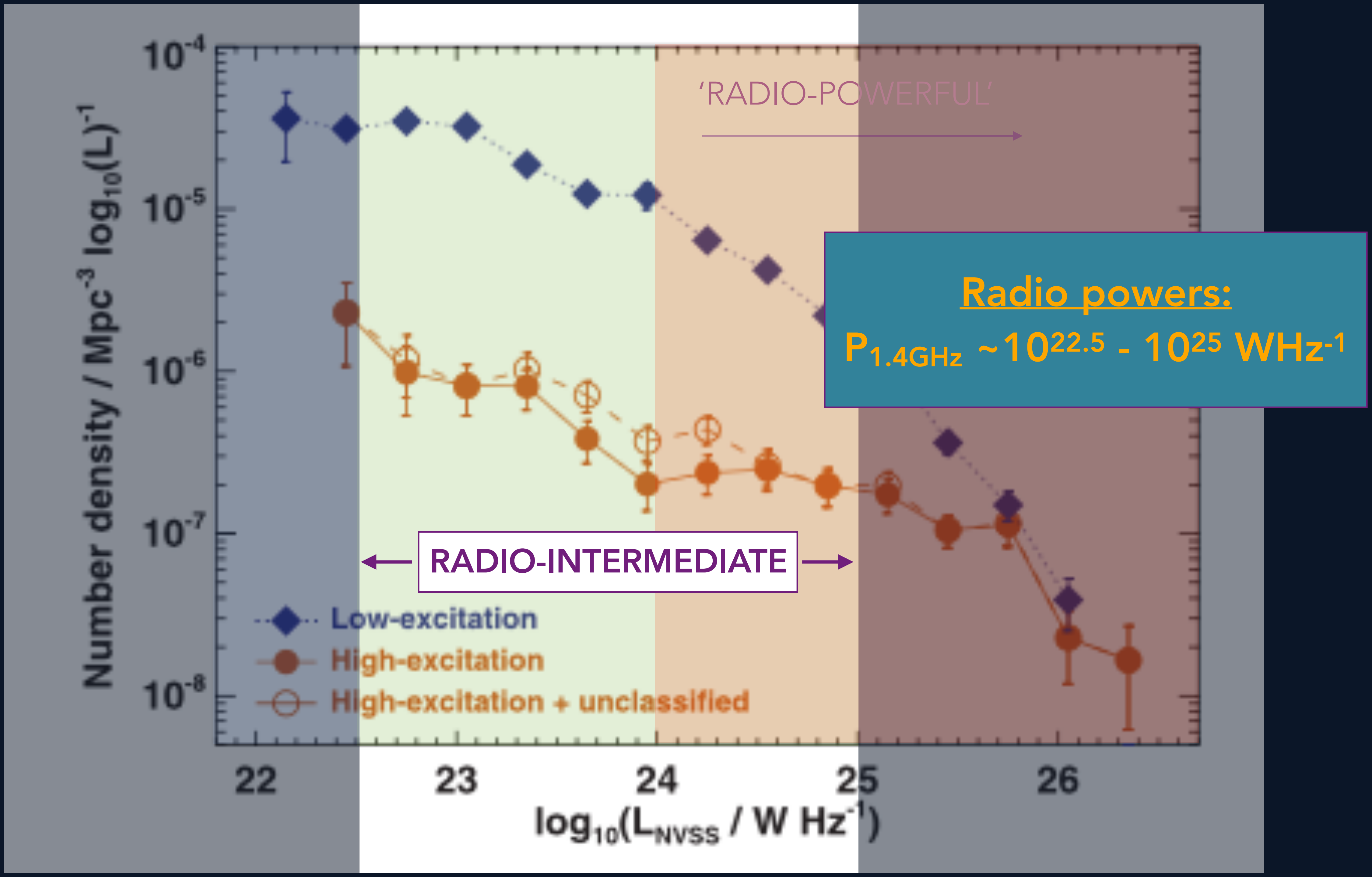
Trump et al. 2011

LOCAL RADIO LUMINOSITY FUNCTION



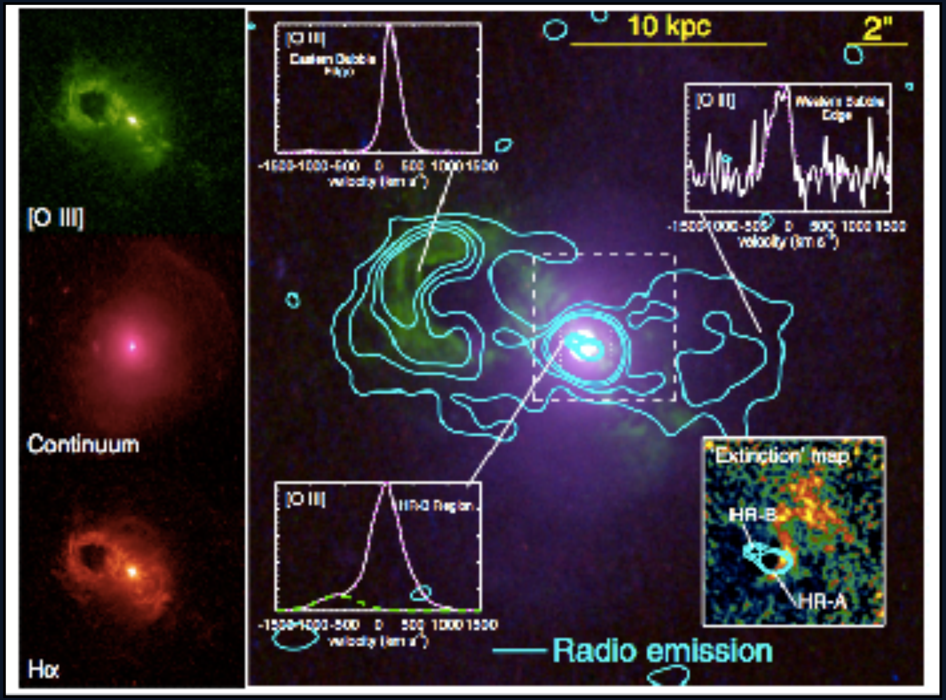
Best & Heckman 2012

RADIO-INTERMEDIATE AGNs



Best & Heckman 2012

RADIO-INTERMEDIATE AGNs

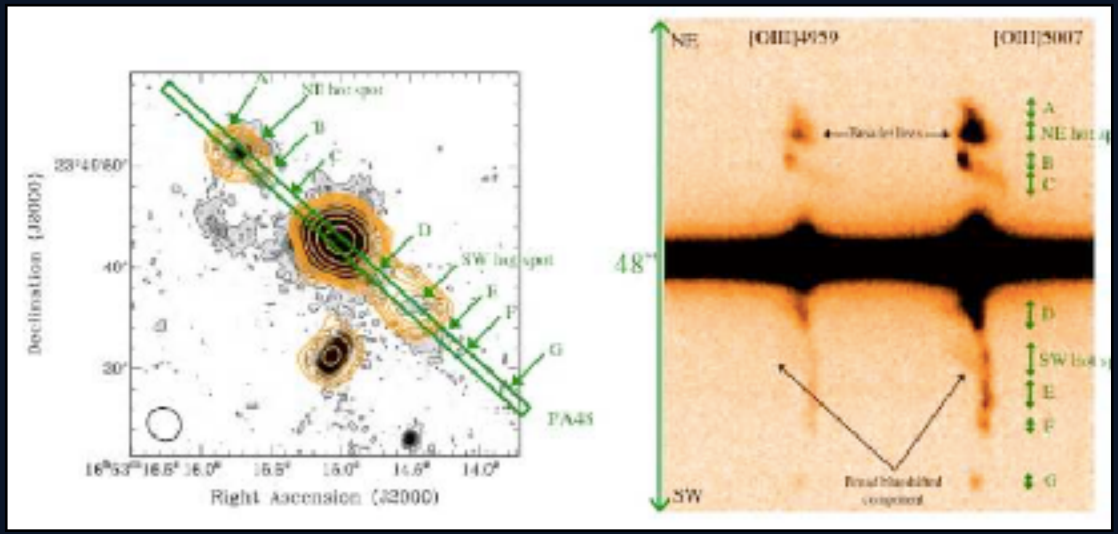


'Teacup' - $P_{1.4\,GHz} \sim 5 \times 10^{23}$ W Hz^{-1} (Harrison et al. 2015)

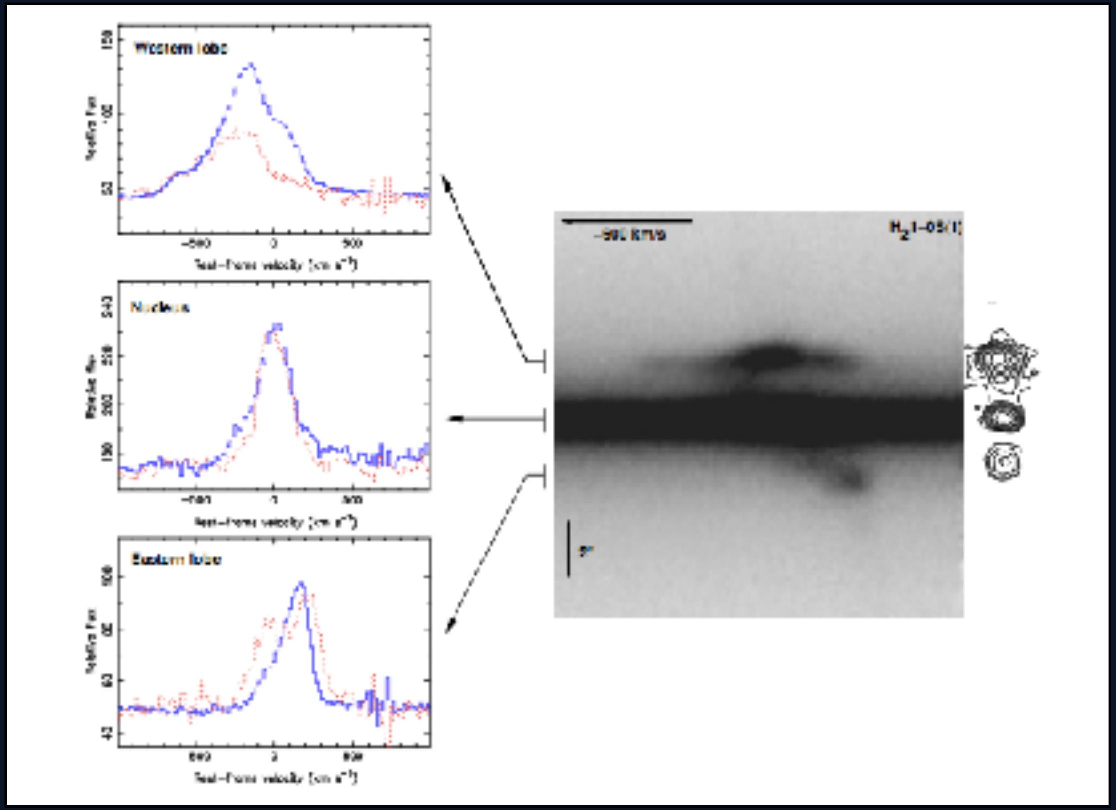
Disturbed gas kinematics

Mullaney et al. (2013):

Broadest [OIII] lines in radio AGNs with $P_{1.4\,GHz} \sim 10^{24}$ W Hz^{-1}

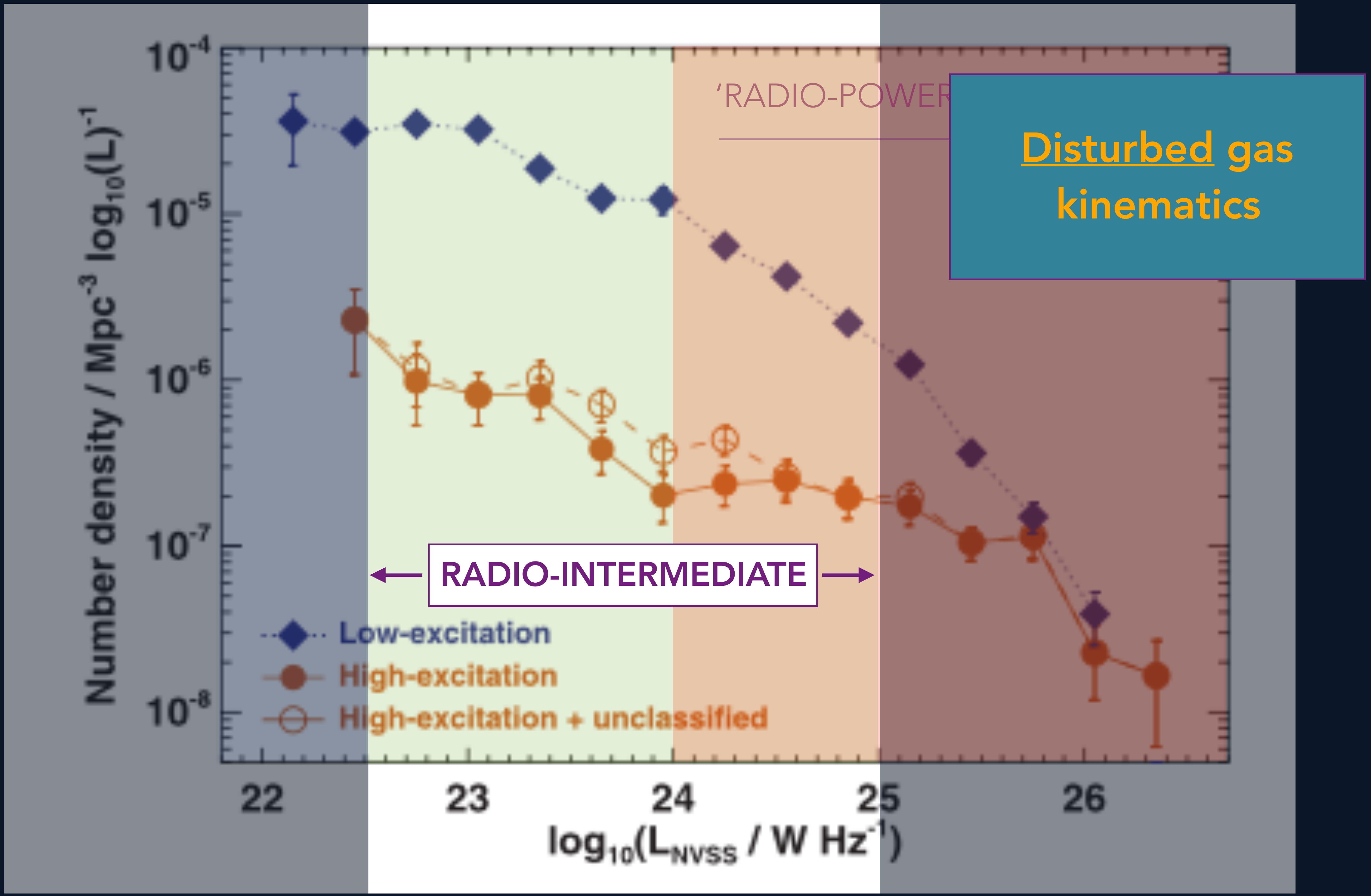


'Beetle' - $P_{1.4\,GHz} \sim 2 \times 10^{23}$ W Hz^{-1} (Villar-Martin et al. 2017)



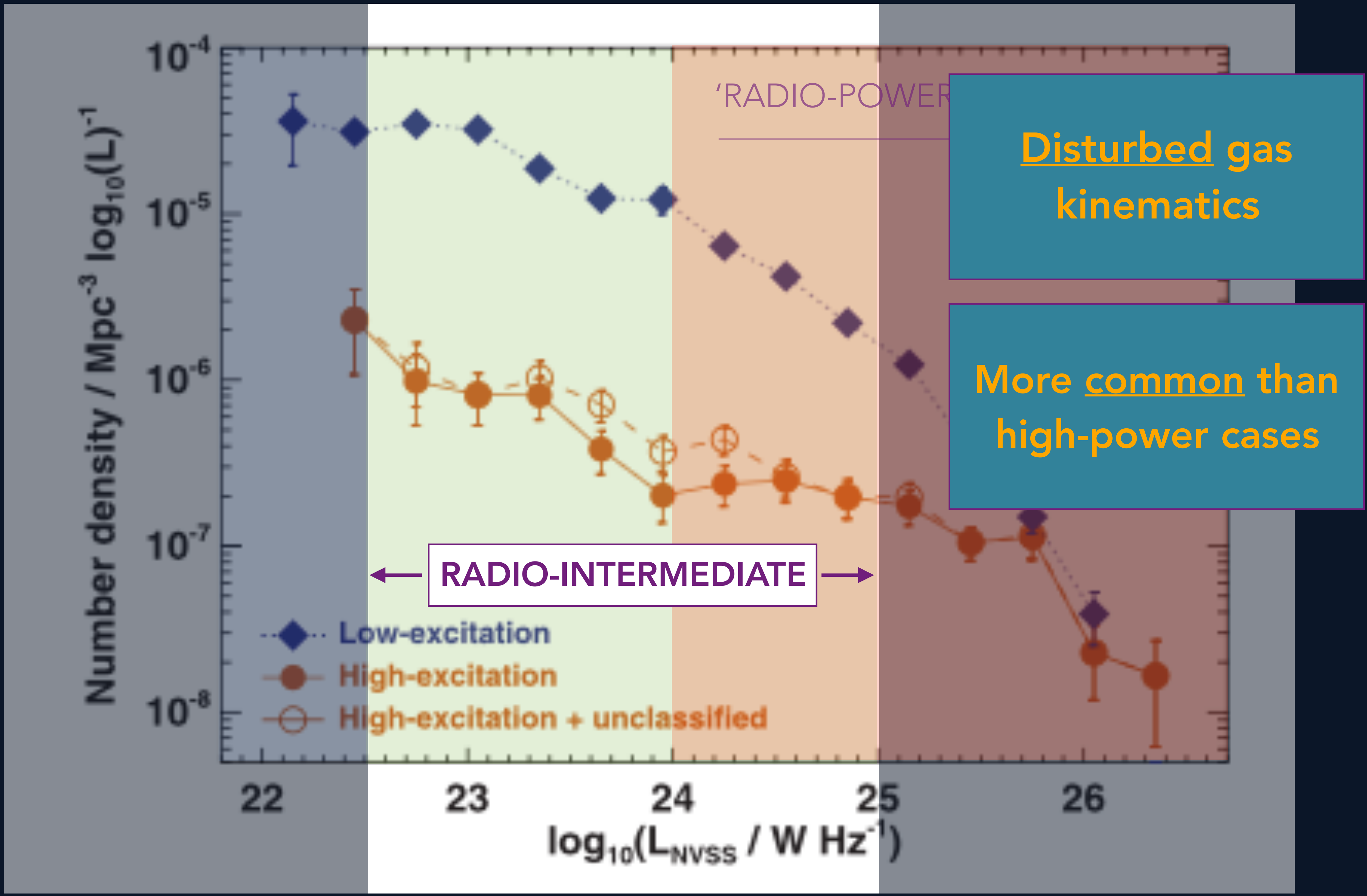
IC 5063 - $P_{1.4\,GHz} \sim 3 \times 10^{23}$ W Hz^{-1}
(Tadhunter et al. 2014)

RADIO-INTERMEDIATE AGNs



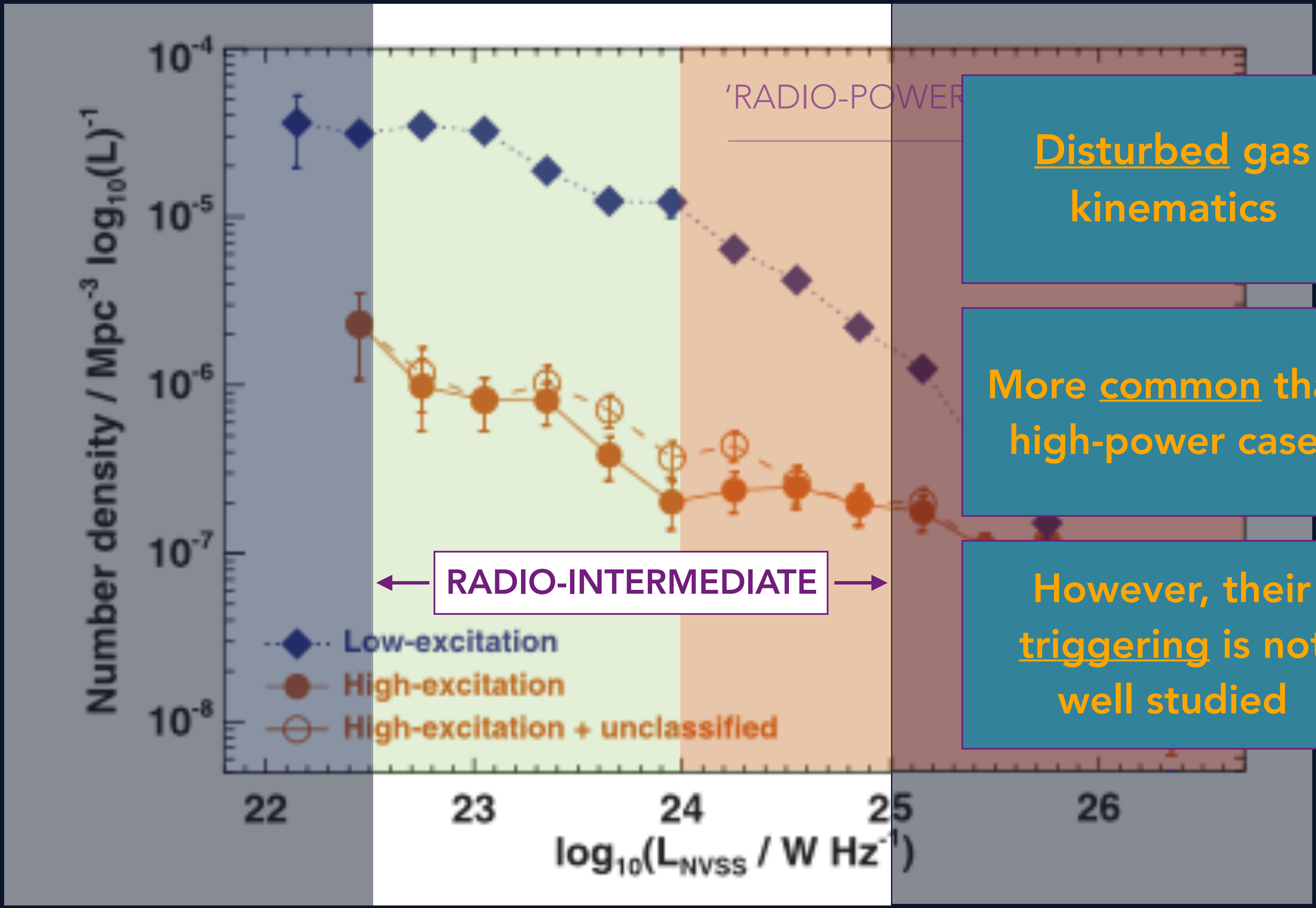
Best & Heckman 2012

RADIO-INTERMEDIATE AGNs



Best & Heckman 2012

RADIO-INTERMEDIATE AGNs



<u>Disturbed</u> gas kinematics

More <u>common</u> than high-power cases

However, their <u>triggering</u> is not well studied

Best & Heckman 2012

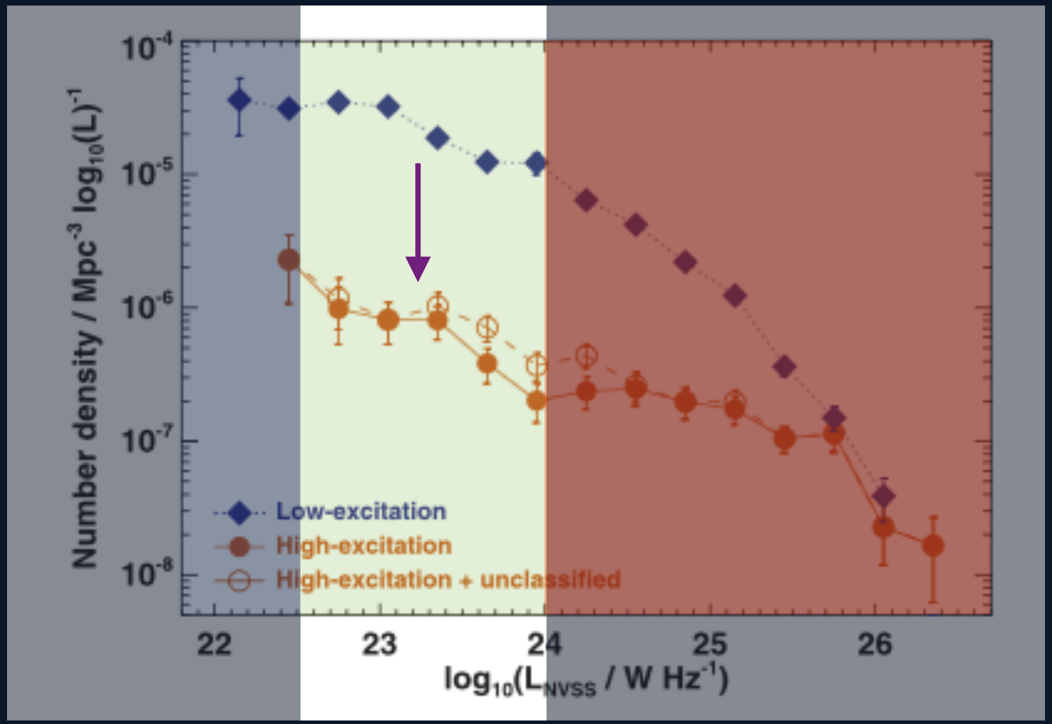
DEEP OPTICAL IMAGING

SAMPLE

32 RIAGNs with $P_{1.4GHz}$ ~$10^{22.5}$ - 10^{24} WHz^{-1}

z < 0.1

HERG optical emission



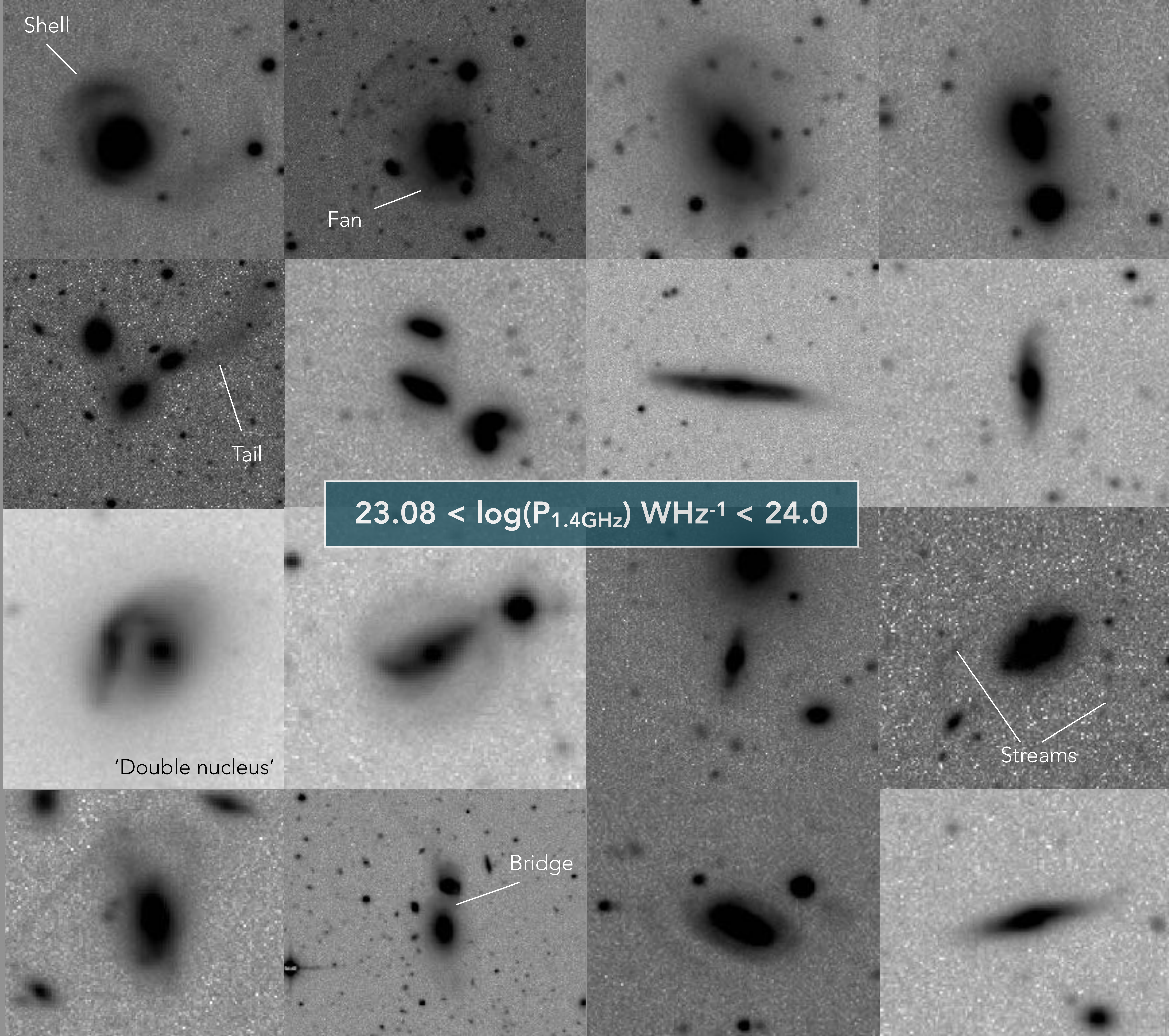
OBSERVATIONS

INT Wide-Field Camera, La Palma

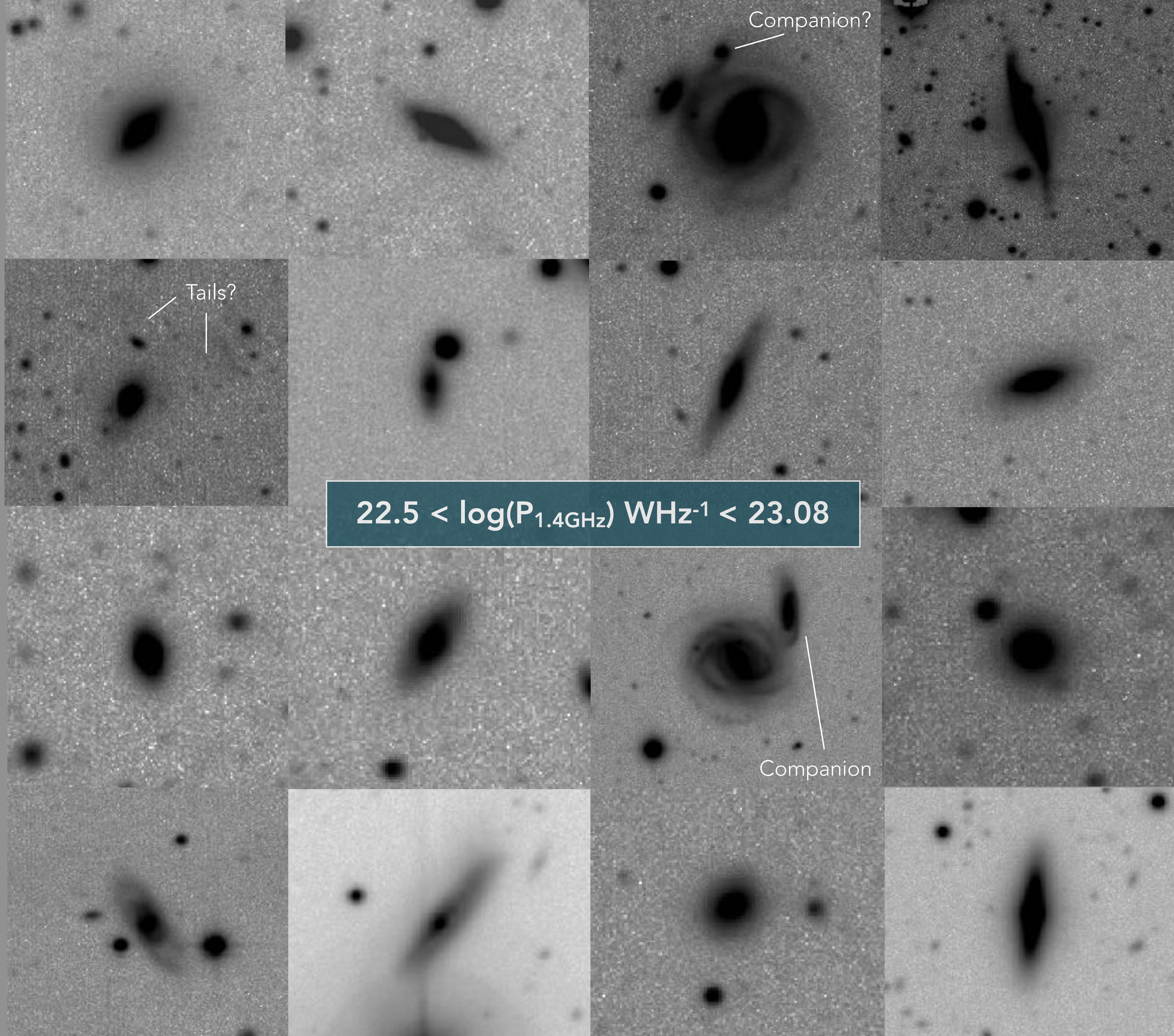
Sloan *r*-band

Limiting SB ~ 27 mag $arcsec^{-2}$

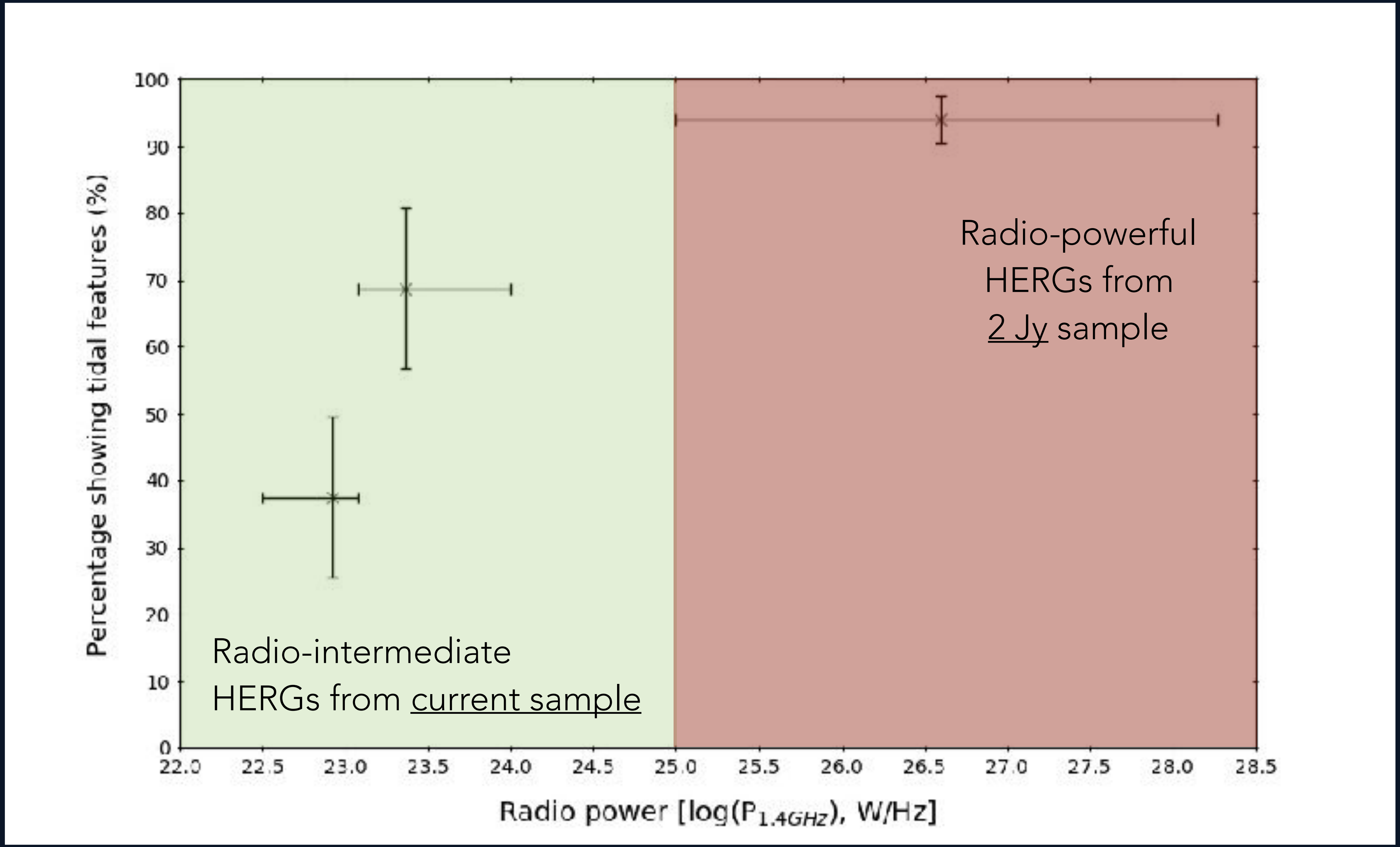
IMAGES



Shell
Fan
Tail
$23.08 < \log(P_{1.4GHz})\ WHz^{-1} < 24.0$
'Double nucleus'
Streams
Bridge


Companion?
Tails?
$22.5 < \log(P_{1.4GHz})$ $WHz^{-1} < 23.08$
Companion

RESULTS - TIDAL FEATURE PROPORTIONS



RESULTS - HOST TYPES

MORPHOLOGY	PROPORTION
DISK/SPIRAL	**21 (66%)**
ELLIPTICAL	5 (16%)
MERGER	6 (18%)

Host morphologies are mainly disk-like

- Lowers chances of significant major merger

3CR, 2 Jy are predominantly giant ellipticals (≥ 95%)

FUTURE WORK - OPTICAL

CURRENT SAMPLE

32 HERGs

$P_{1.4GHz} \sim 10^{22.5} - 10^{24}$ WHz^{-1}

$z < 0.1$

+

INT (LA PALMA)

28 HERGs

$P_{1.4GHz} \sim 10^{24} - 10^{25}$ WHz^{-1}

$z < 0.15$

NTT (CHILE)

30 HERGs

$P_{1.4GHz} \sim 10^{23} - 10^{25}$ WHz^{-1}

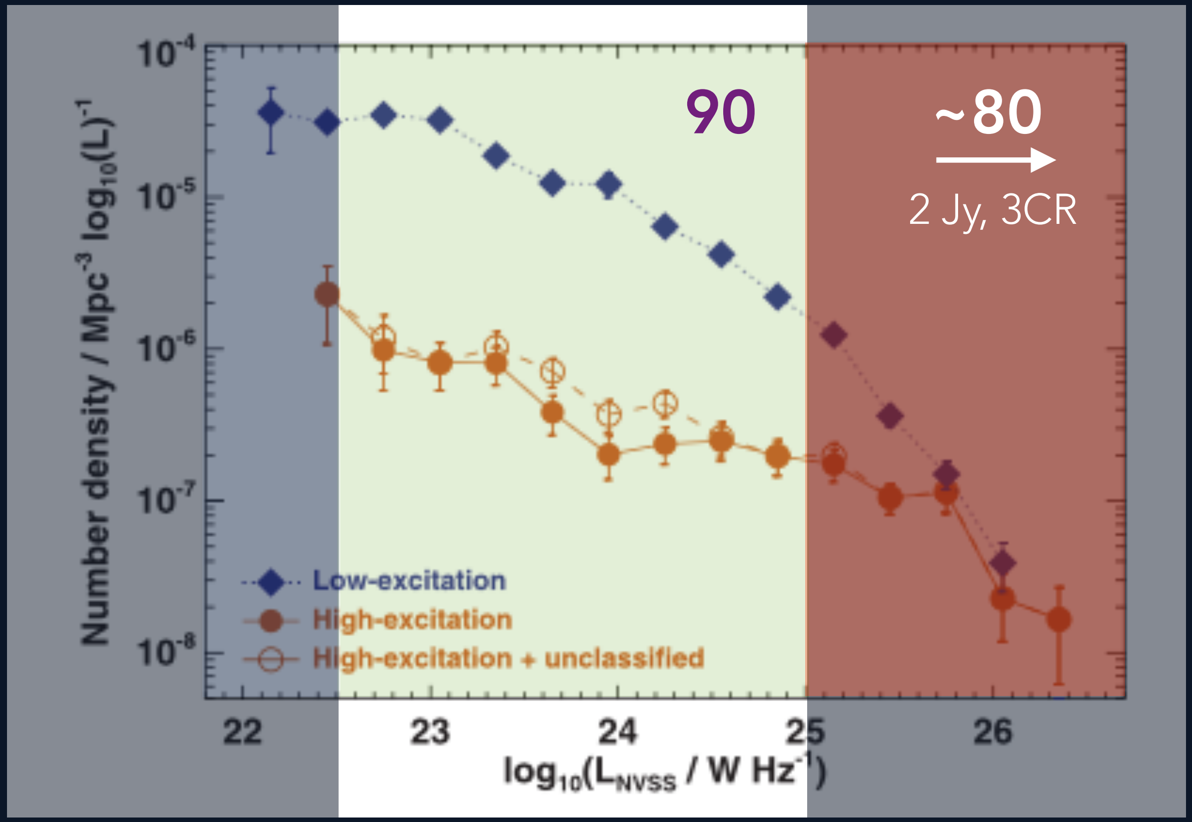
$0.1 < z < 0.2$

TOTAL

90 HERGs

$P_{1.4GHz} \sim 10^{22.5} - 10^{25}$ WHz^{-1}

$z < 0.2$



FUTURE WORK - RADIO PROPERTIES

VLA

High-resolution L-/C-band observations

20 HERGs; $P_{1.4GHz}$ ~10^{23} - 10^{24} WHz^{-1}

- Existing deep optical images
- Compact at FIRST res. (~5″)

Two main goals…

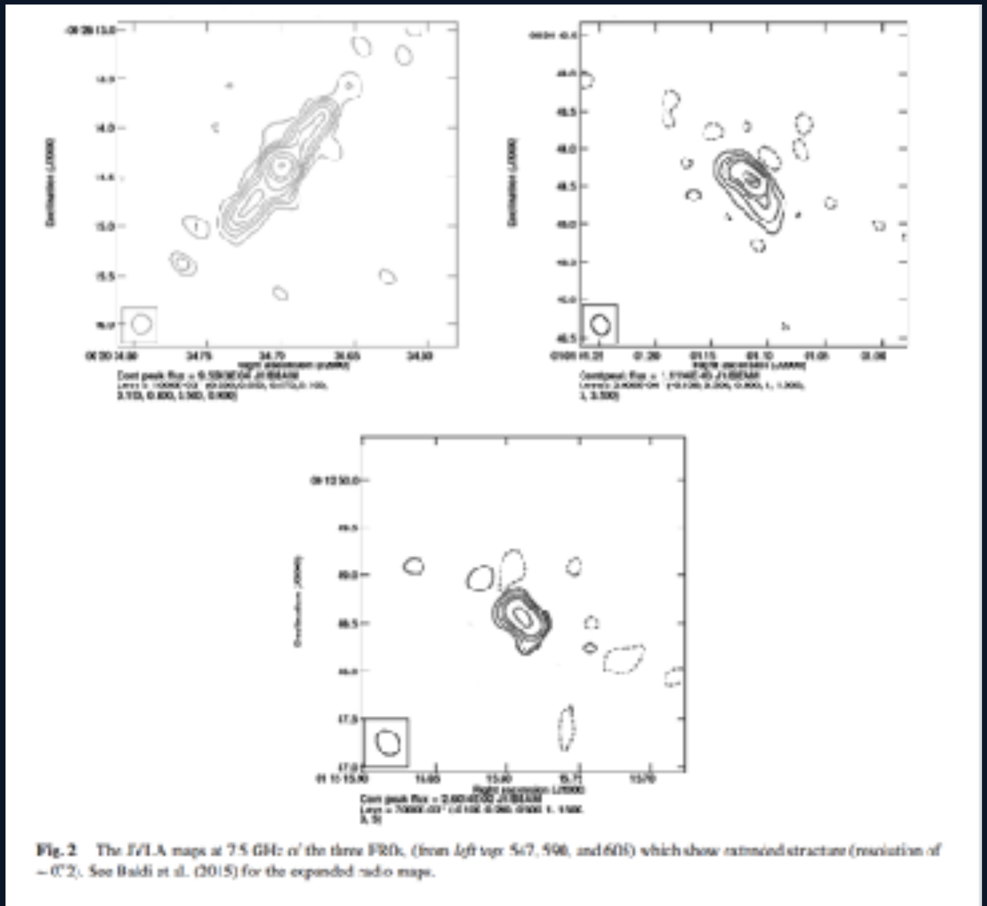
NRAO

FUTURE WORK - RADIO PROPERTIES

INVESTIGATE FRII/HERG CONNECTION

Common accretion mode or driven by environment?

'Mini-FRIIs' or FR0s?



Baldi, Capetti & Giovannini (2015)

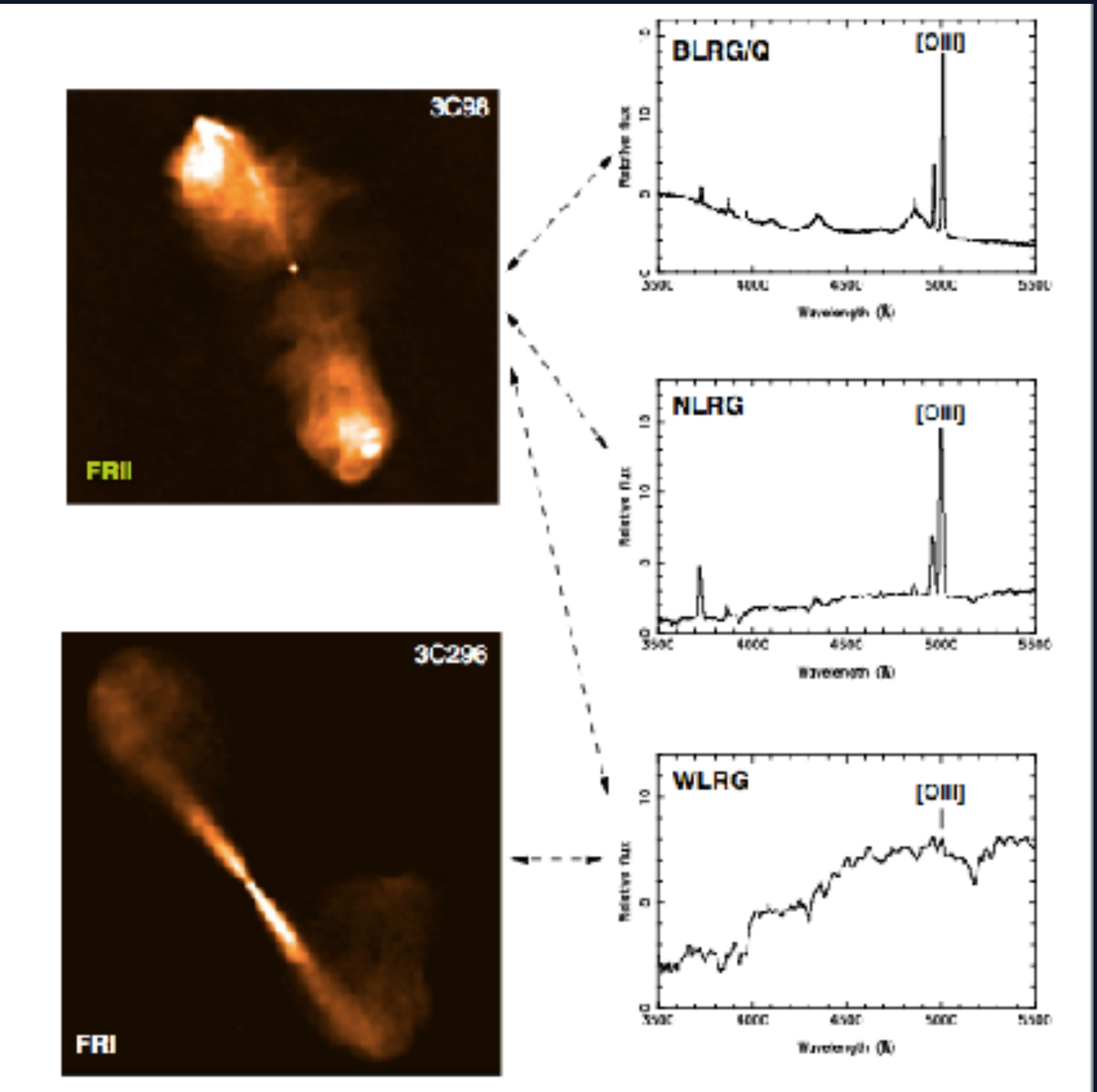


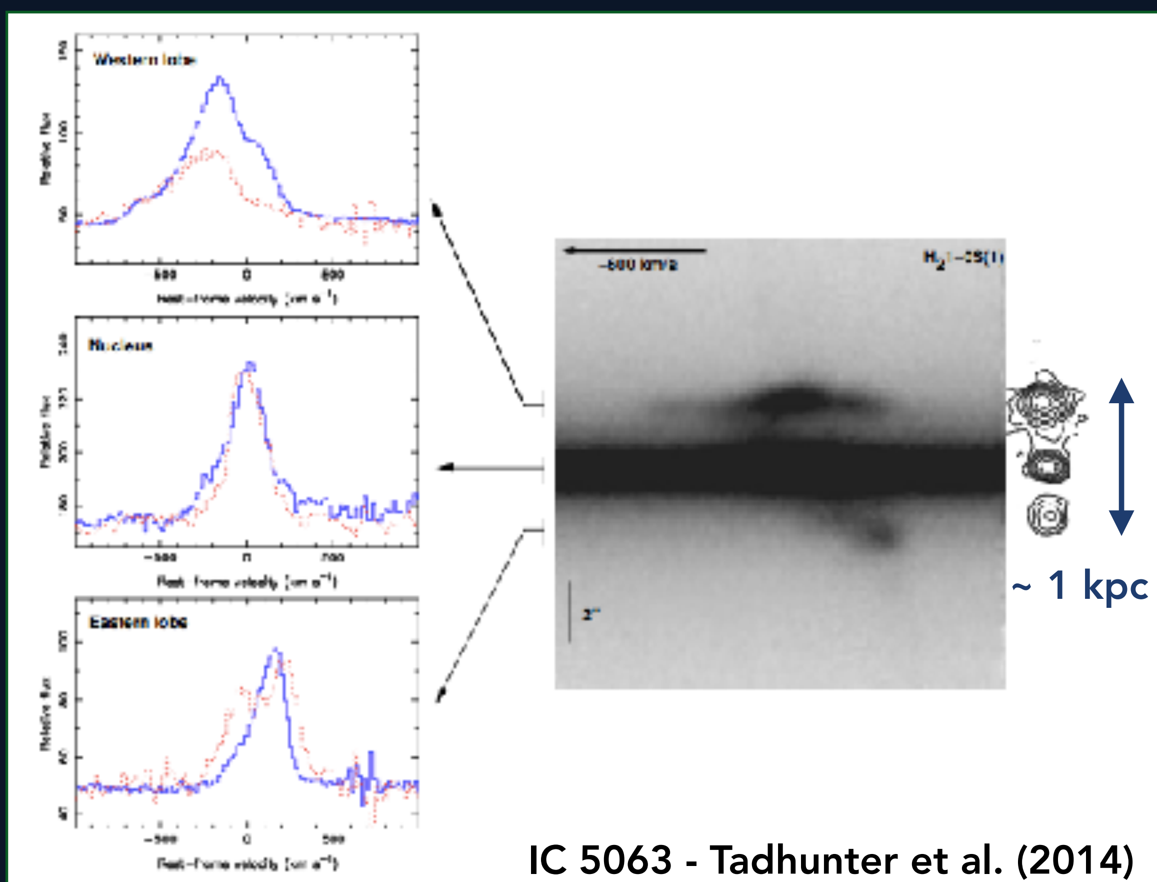
Fig. 1 The main radio and optical classifications of radio AGN. Left radio morphological classifications. Right optical spectroscopic classifications. The dashed lines indicate links between the radio and optical classifications. Credits: the radio images were taken from http://www.jb.man.ac.uk/atlas

Tadhunter (2016)

FUTURE WORK - RADIO PROPERTIES

SCALES FOR RADIO JET FEEDBACK

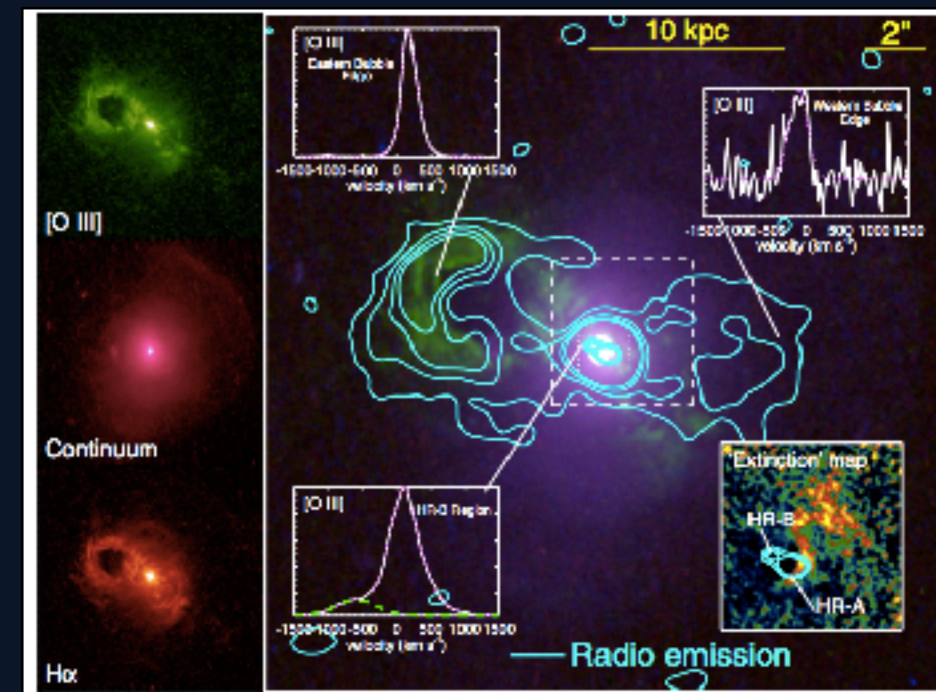
NLR (~ 1 kpc)



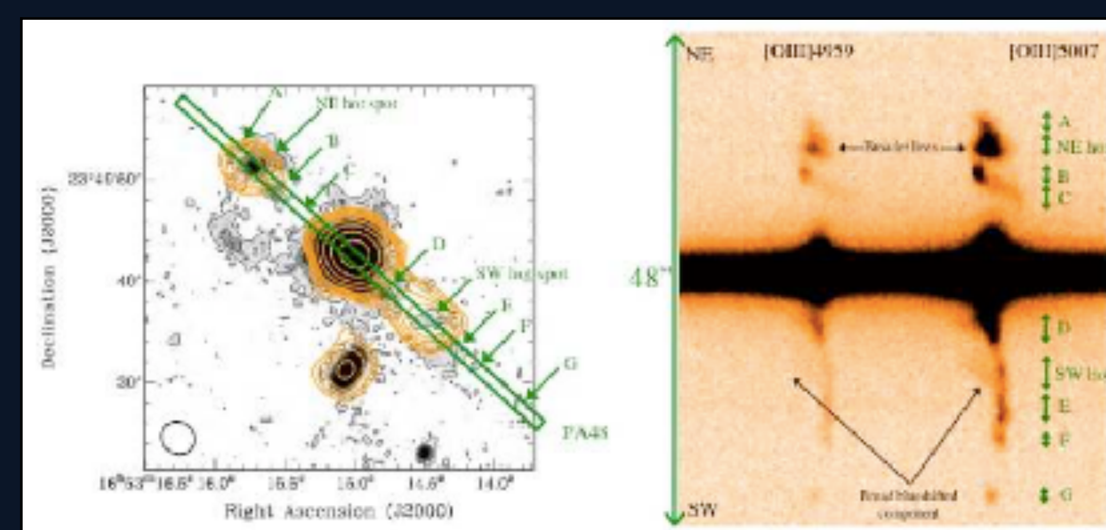
IC 5063 - Tadhunter et al. (2014)

or

'Teacup' - (Harrison et al 2015)



Bulge (up to ~10 kpc)?

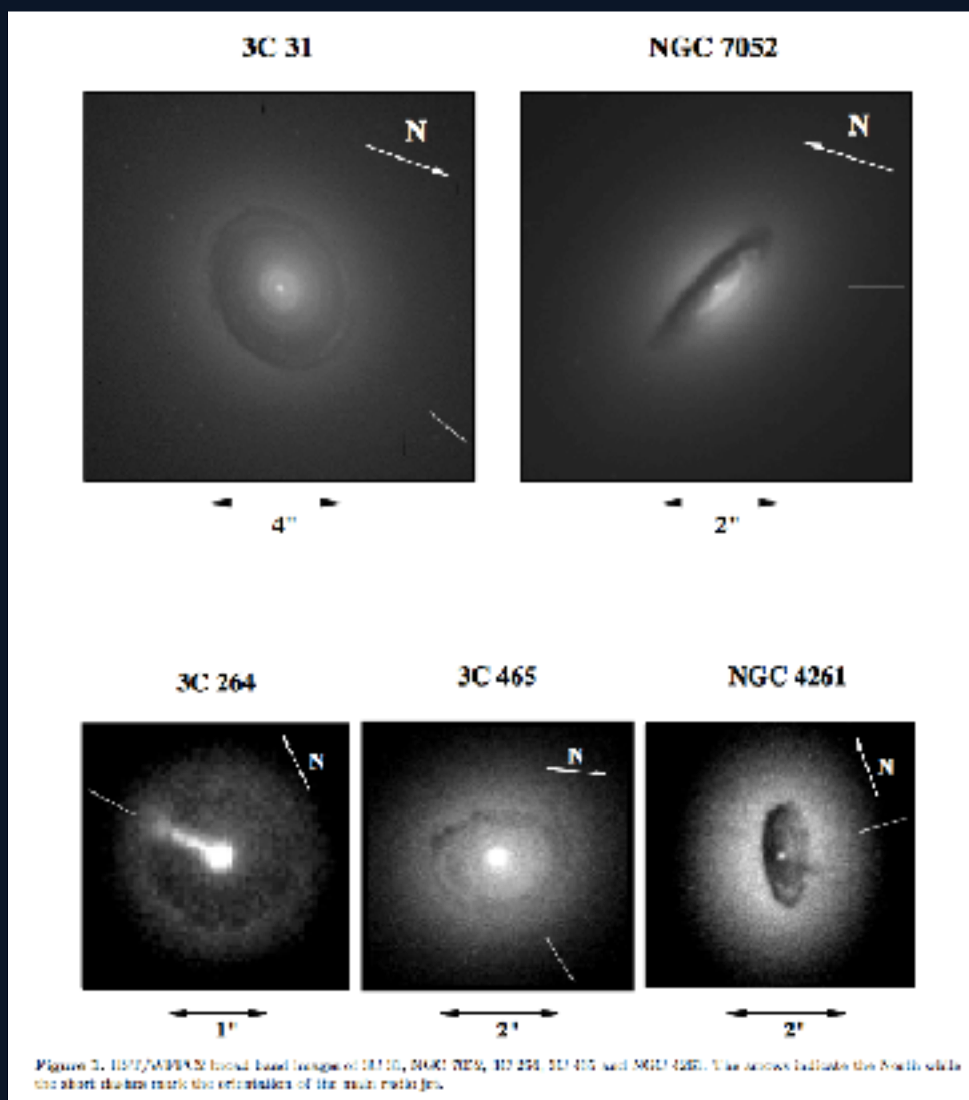


'Beetle' - (Villar-Martin et al. 2017)

FUTURE WORK - RADIO PROPERTIES

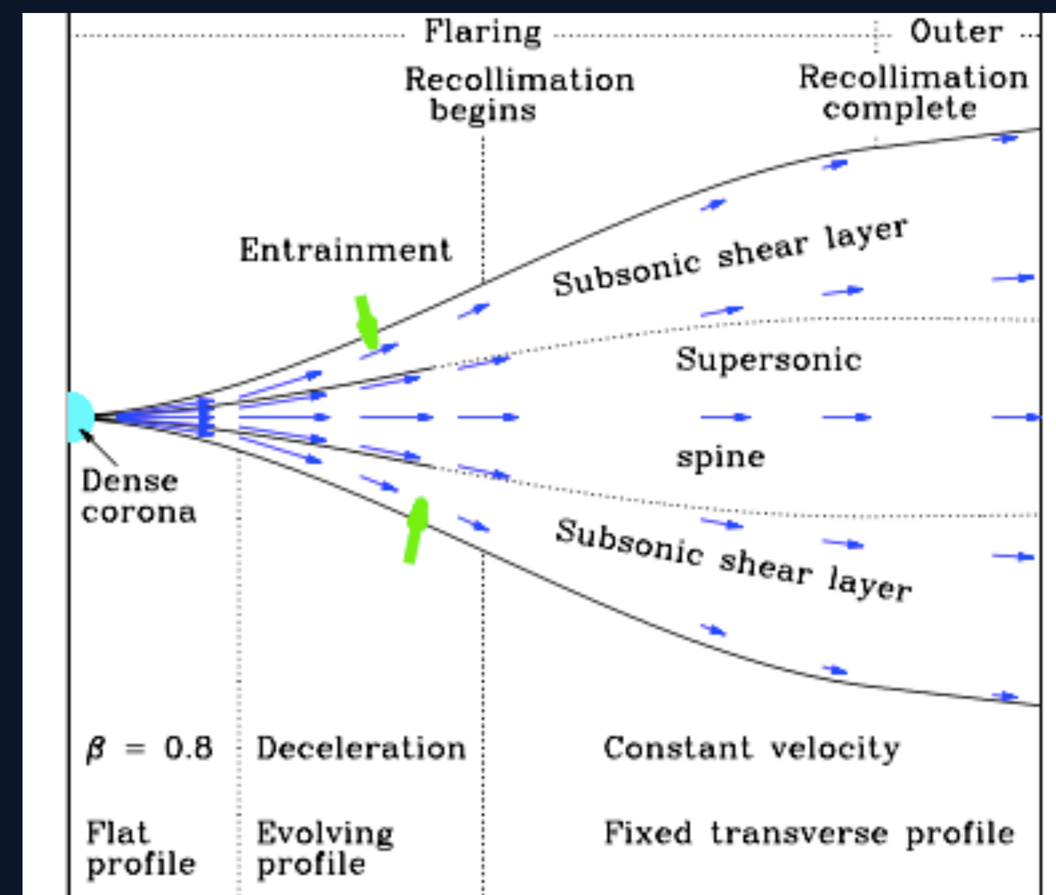
HOST GALAXY PROPERTIES

Jet orientation relative to disks?



Capetti & Celotti (1998)

Entrainment more likely in galaxies with bulges?



Laing & Bridle (2014)

SUMMARY

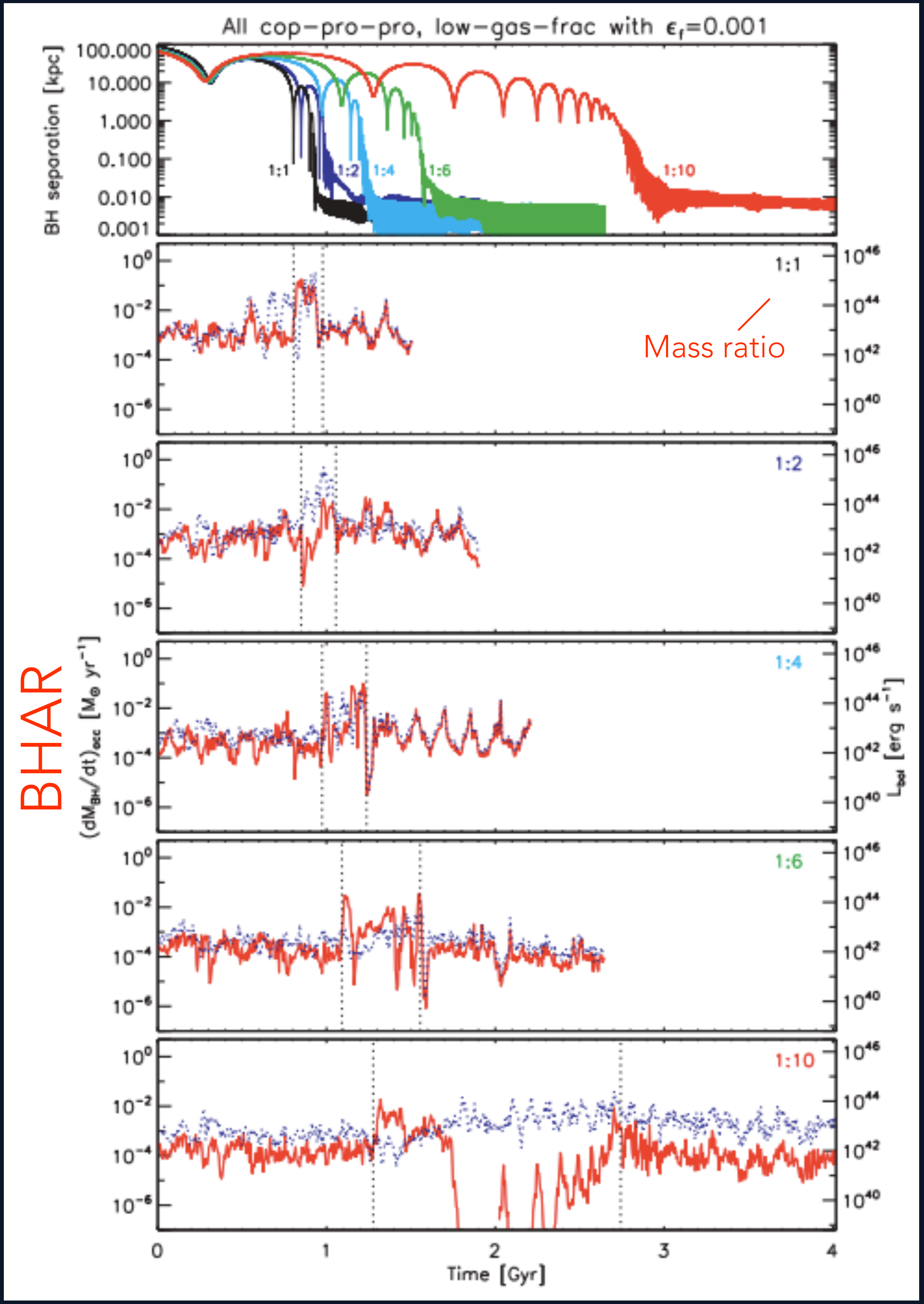
Radio-intermediate HERGs have reduced proportion of tidal features and more disk-like hosts than their radio-powerful counterparts

Implies merger-based triggering is less important

High-res. VLA observations will provide information about radio morphologies, scales of radio-jet feedback and relationship with host galaxy properties

FUTURE WORK

- Environments
- Control sample
- Host morphologies
- Statistics will improve with new observations

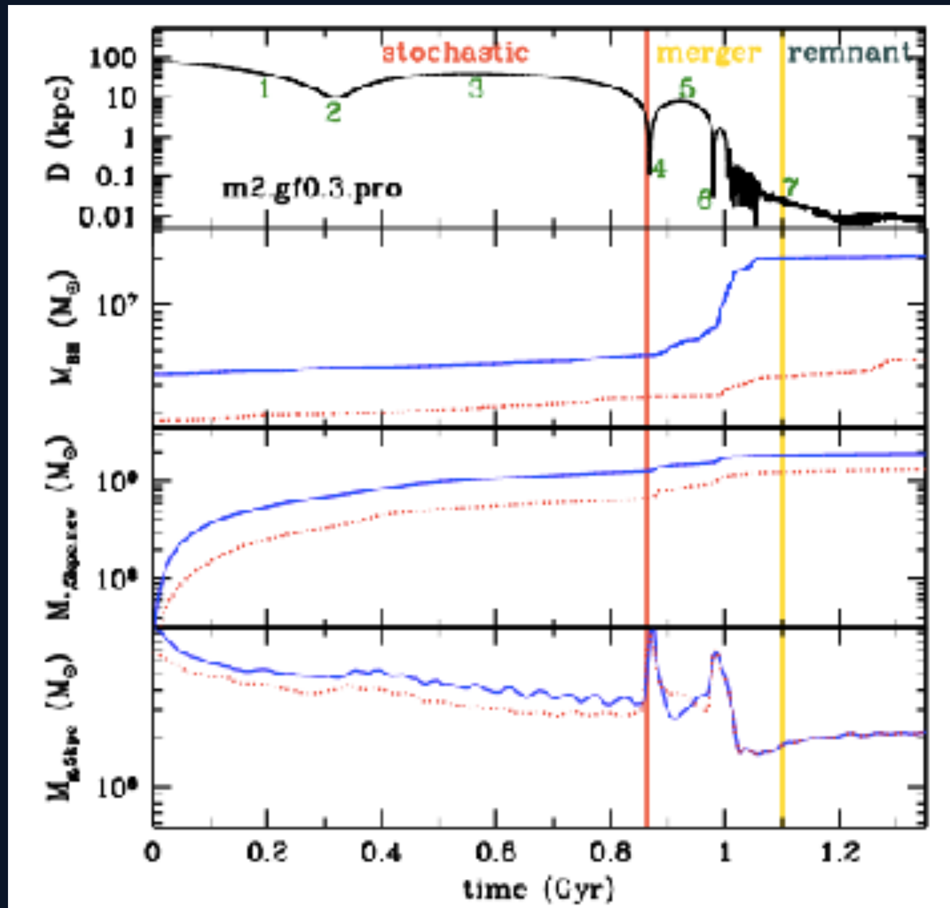


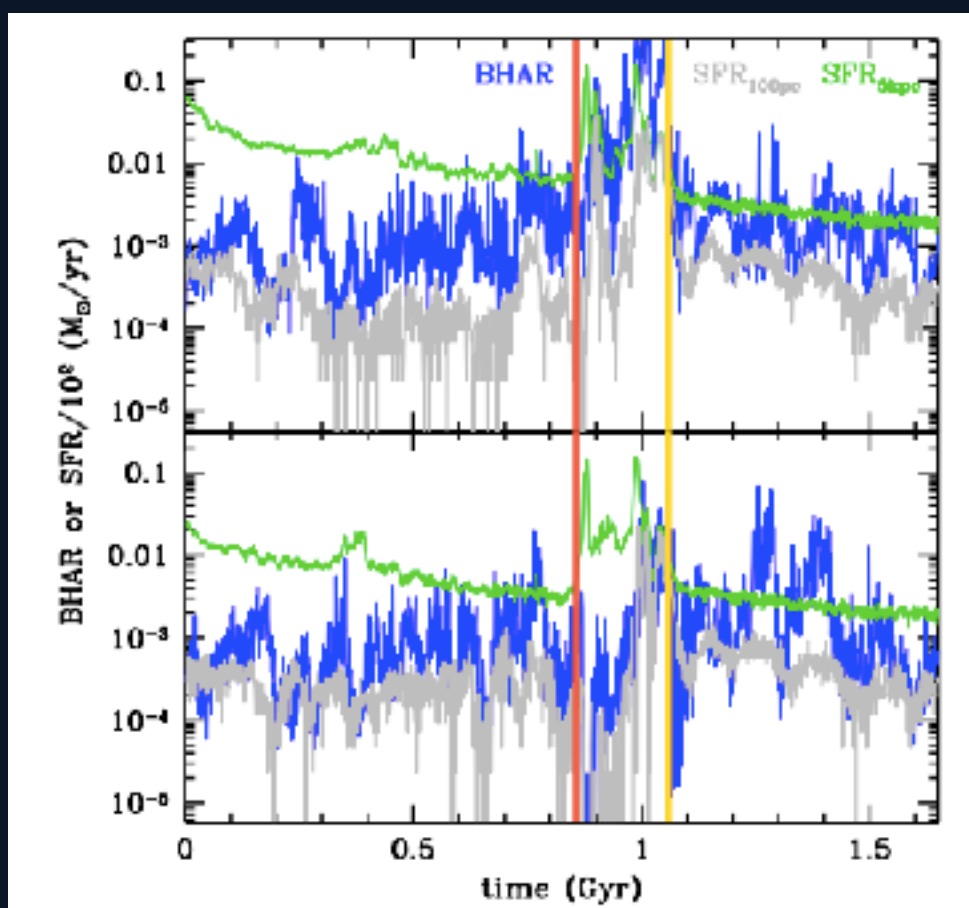
More minor mergers

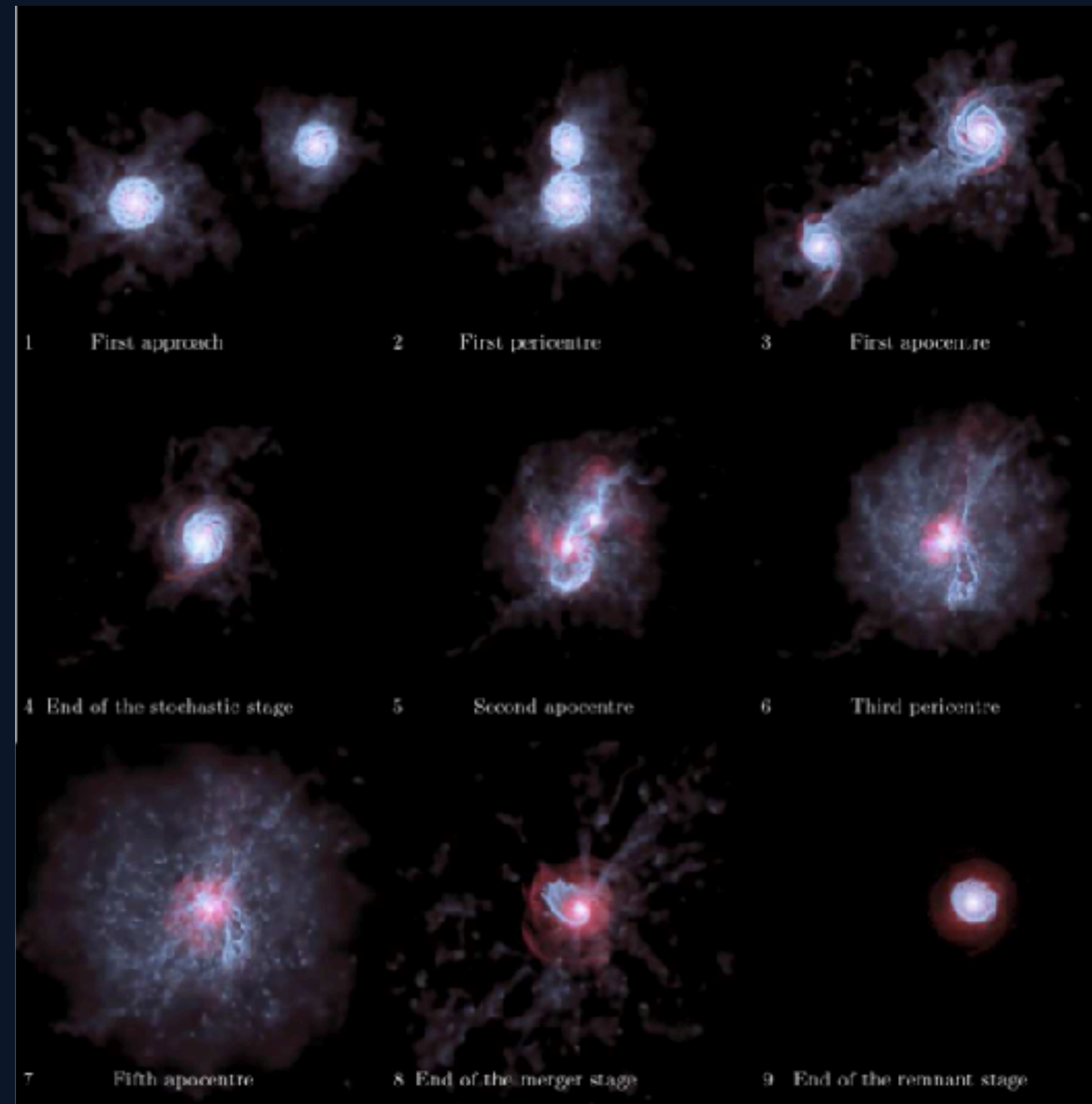
Capelo et al. (2015)

<u>Multiple peaks</u> in BH accretion rate throughout galaxy mergers

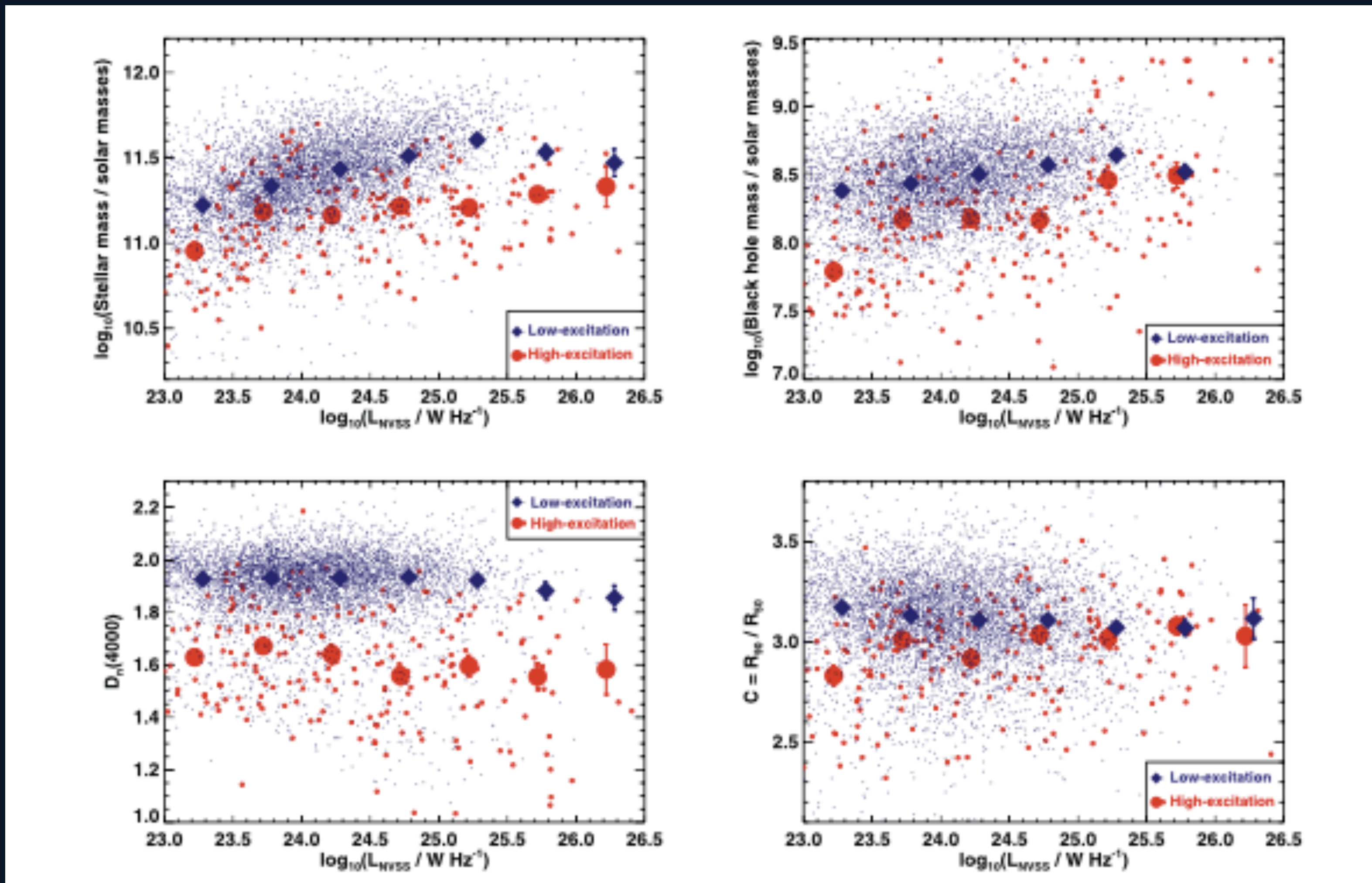
Timescale of separations <u>comparable with life-cycle times</u> of radio sources: **~10^7-10^8 yrs** (Morganti 2017)



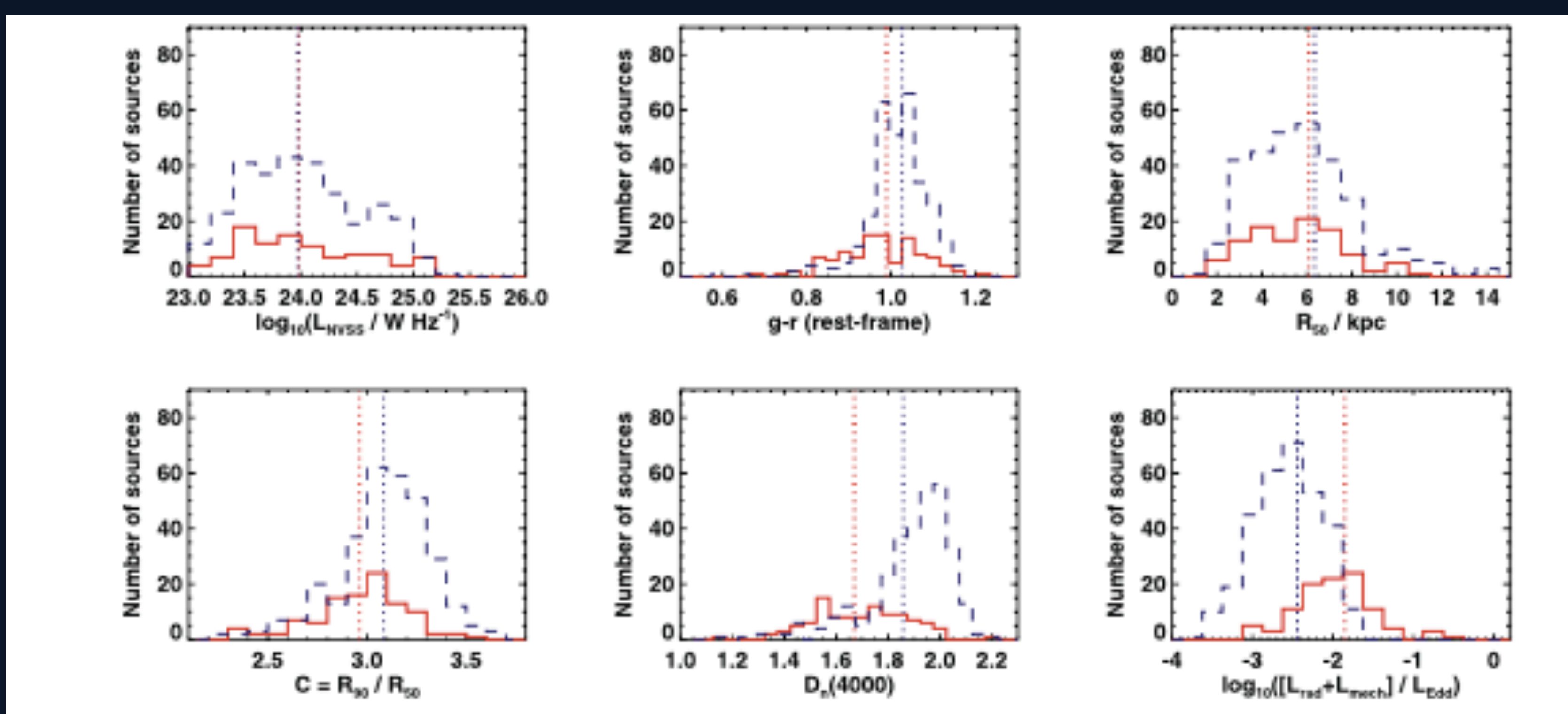




Volonteri et al. (2015)



HERGs have systematically **lower stellar masses**, **D_n(4000)** and **black hole masses** for RI cases



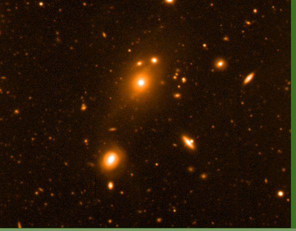
… also **bluer** colours, **less diffuse** optical emission

→ younger stellar populations

Best & Heckman 2012

RESULTS - TIDAL FEATURE TYPES

TF TYPE	RI Sample		2 Jy
$P_{1.4GHz}$	$10^{22.5}$ - $10^{23.08}$ WHz^{-1}	$10^{23.08}$ - 10^{24} WHz^{-1}	> 10^{25} WHz^{-1}
TAIL	54%	50%	17%
FAN	27%	13%	16%
SHELL	19%	21%	32%
BRIDGE	-	8%	9%
DOUBLE NUCLEUS	-	4%	10%
IRREGULAR	-	4%	9%



Results

Evidence for galaxy interactions in PRGs

PRELIMINARY

- 81% of the 3CR sample show signs of morphological disturbance

3CR (84)	SLRG (62 – 74%)	WLRG (22 – 26%)
81%	82%	77%
2Jy (46)	SLRG (35 – 76%)	WLRG (11 – 24%)
85%	94%	27%

73 3CR + 46 2Jy = 119 PRGs of which 83% show disturbed morphologies

Ramos Almeida, Doña-Girón, Tadhunter et al. in prep.