High-energy view of hard X-ray selected radio galaxies

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12th INTEGRAL Conference - 1st AHEAD Gamma-ray Workshop

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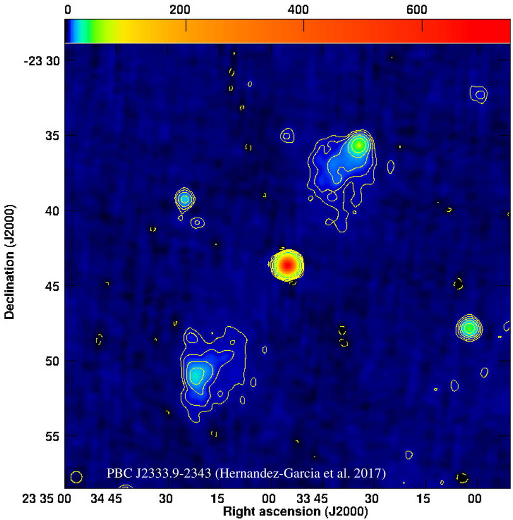
Outline

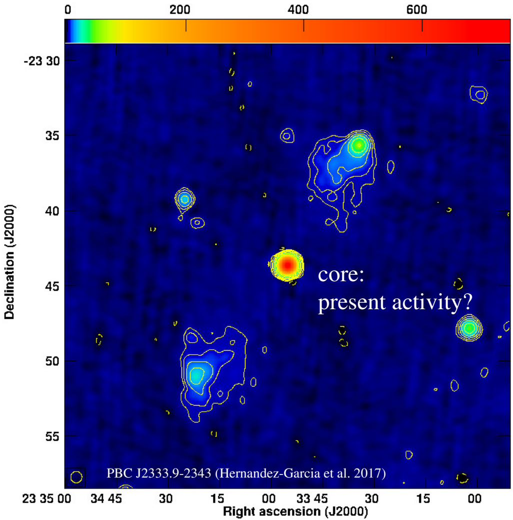
Broad-band study of the first sample of radio galaxies selected in the hard X-rays (64 AGNs from the INTEGRAL and Swift/BAT surveys with an extended radio morphology; Bassani et al. 2016) – see G. Bruni's talk

- Giant radio galaxies: X-ray properties and radio connection
- Absorption properties
  - The X-ray column density distribution
  - Relationship with the radio and mid-IR absorption

GRGs: X-ray properties and radio connection



GRGs: X-ray properties and radio connection



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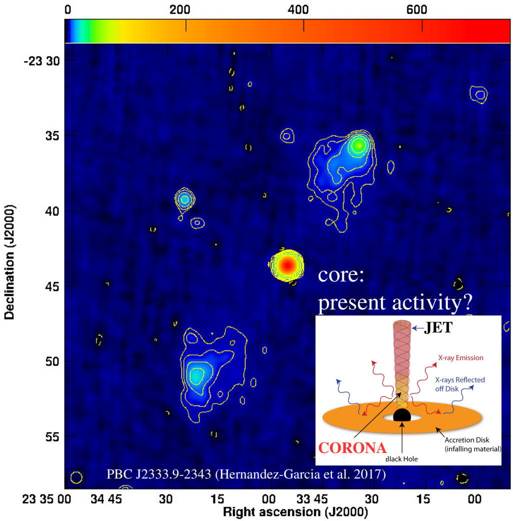

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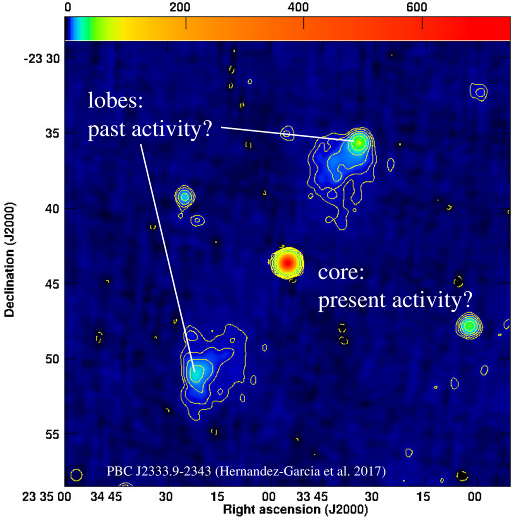


GRGs: X-ray properties and radio connection

Broad-band X-ray data

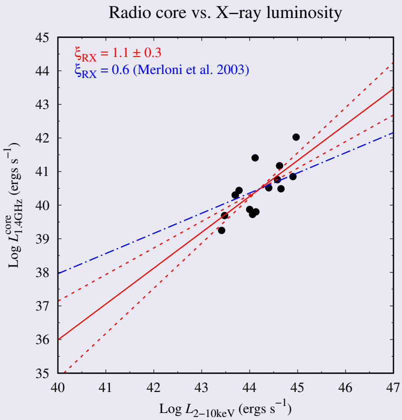
The X-ray properties of the hard X-ray selected GRGs have been studied in Ursini et al. (2018b)

Name	z	Optical class	log $M_{\rm BH}$	**X-ray data**	Ref.	Radio data	Ref.
0318+684	0.090100	Sy1.9	-	**XMM+NuSTAR+BAT+IBIS**	Ursini+18b	*VLA*	Lara+01
PKS 0707-35	0.110800	Sy2	-	**NuSTAR+BAT**	"	*ATCA*	Saripalli+13
Mrk 1498	0.054700	Sy1.9	8.59	**XMM+NuSTAR+BAT**	"	*VLA*	Schoenmakers+00
PKS 2331-240	0.047700	Sy1.9	8.75	**XMM+NuSTAR+BAT**	"	*VLBA*	Hernandez-Garcia+17
PKS 2356-61	0.096306	Sy2	8.96	**NuSTAR+BAT**	"	*ATCA*	Subrahmanyan+96
B3 0309+411b	0.134000	Sy1	-	**XMM+BAT+IBIS**	Molina+08	*VLA*	Schoenmakers+00
4C 73.08	0.058100	Sy2	-	**XMM+NuSTAR**	Ursini+18a	*VLA*	Lara+01
HE 1434-1600	0.144537	BLQSO	8.64	**Swift/XRT+BAT**	Panessa+16	*VLA*	Letawe+04
IGR J14488-4008	0.123	Sy1.5	8.58	**XMM+BAT+IBIS**	Molina+15	*GMRT*	Molina+15
4C 63.22	0.20400	Sy1	-	**Swift/XRT+BAT**	Panessa+16	*VLA*	Lara+01
4C 34.47	0.20600	Sy1	8.01	**XMM**	Page+04	*WSRT*	Jagers+82
IGR J17488-2338	0.240	Sy1.2	9.11	**XMM+IBIS**	Molina+14	*VLA*	Condon+98
PKS 2014-55	0.060629	Sy2	-	**Swift/XRT+BAT**	Panessa+16	*ATCA*	Saripalli+07
4C 74.26	0.10400	Sy1	9.37	**XMM+BAT+IBIS** **NuSTAR+XRT**	Molina+08 Lohfink+17	*VLA*	Lara+01

GRGs: X-ray properties and radio connection

Radio–X-ray relationship I. Fundamental plane

The radio core and X-ray luminosities are correlated, as expected from the fundamental plane of black hole activity (Merloni et al. 2003).
The slope is significantly larger than the Merloni et al. correlation...



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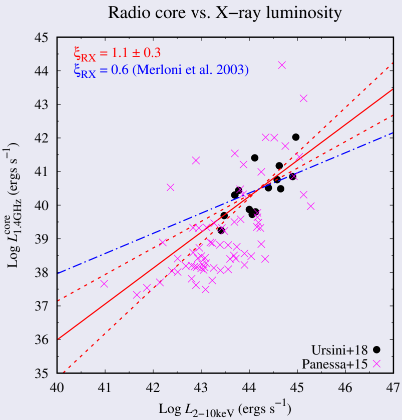
... And consistent with hard X-ray selected AGNs (Panessa et al. 2015).



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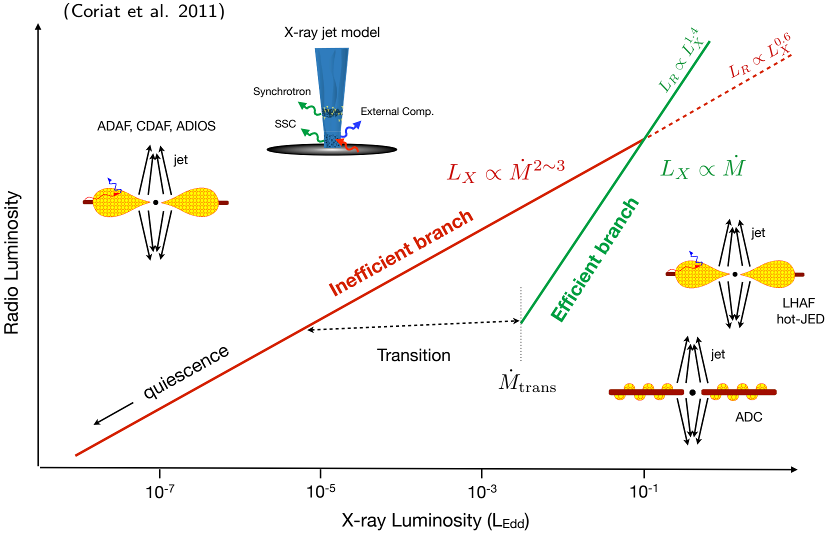

GRGs: X-ray properties and radio connection

Radio–X-ray relationship II. Present vs. past activity

Can we compare the present level of activity with the past one?
From the X-ray luminosity $\longrightarrow \mathbf{L^{X}_{bol}}$ ('current' bolometric luminosity), to be compared with:

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(a) From the radio lobes
$\longrightarrow \mathbf{L_{bol}^{radio}}$
$\log(L_{1.4\mathrm{GHz}}^{\mathrm{lobes}}/L_{\mathrm{bol}}) = -3.57$
(Van Velzen et al. 2015)

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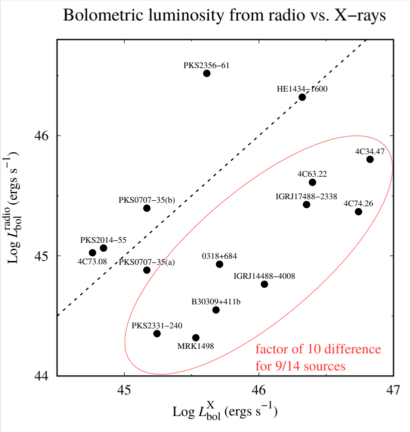

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From the X-ray luminosity $\longrightarrow$ $\mathbf{L^X_{bol}}$ ('current' bolometric luminosity), to be compared with:

(b) From the 151-MHz luminosity $\longrightarrow$ **the jet power** $Q_j = 3 \times 10^{38} \mathcal{L}_{151}^{6/7}$ W (Willott et al. 1999)

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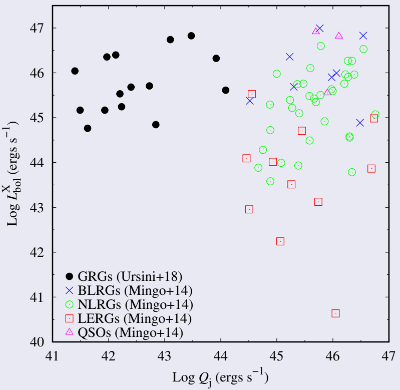
(Willott et al. 1999)
Compare with luminous radio galaxies (Mingo et al. 2014)

X–ray–derived bolometric luminosity vs. jet power



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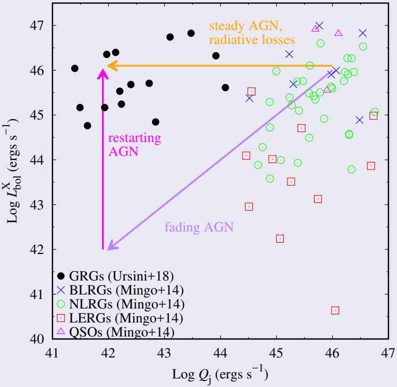
Consistent with restarting activity! (Bruni et al. subm.)

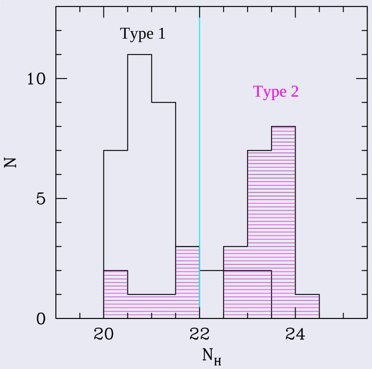
X−ray−derived bolometric luminosity vs. jet power



Absorption properties

X-ray absorption

Column density distribution (Panessa et al. 2016): consistent with the unified model of AGNs...



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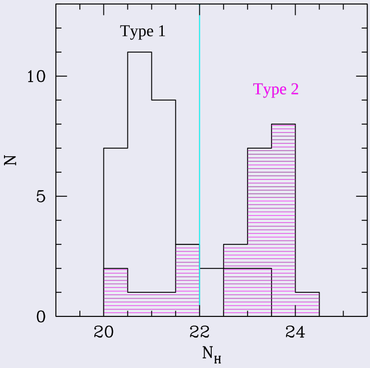
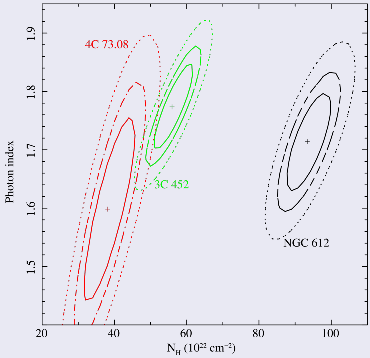


... But no evidence for Compton-thick radio galaxies (Ursini et al. 2018a)



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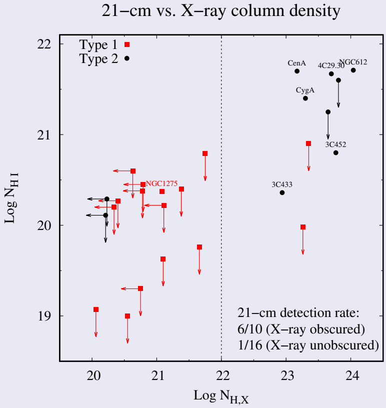

Absorption properties

X-ray absorption

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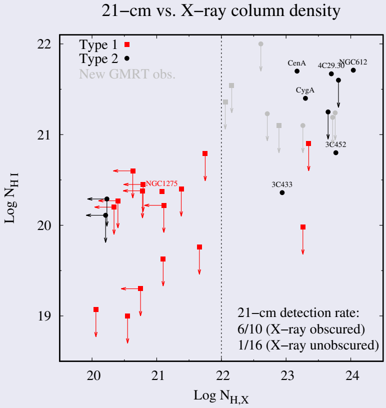
... New 21-cm observations with GMRT show that the scenario is likely more complex (work in progress; collaboration with R. Morganti, V. Moss, S. Murthy).



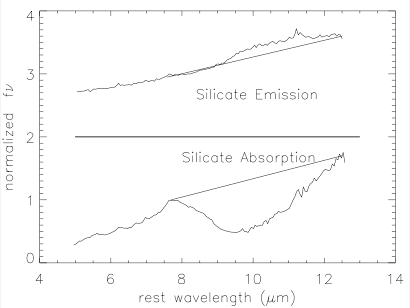
Absorption properties

Radio/X-ray/mid-IR absorption

The strength of the silicate feature at 9.7 μm ($S = \ln F(\lambda_p)/F_C(\lambda_p)$) is a diagnostic of the dusty torus.

- $S > 0 \longrightarrow$ emission (expected in Type 1)
- $S < 0 \longrightarrow$ absorption (expected in Type 2)
- $S < -1 \longrightarrow$ deep absorption, not entirely explained by torus (García-González et al. 2017)

Deep silicate absorption indicates a contamination from obscuration in the host galaxy (Goulding et al. 2012, Hatziminaoglou et al. 2015).

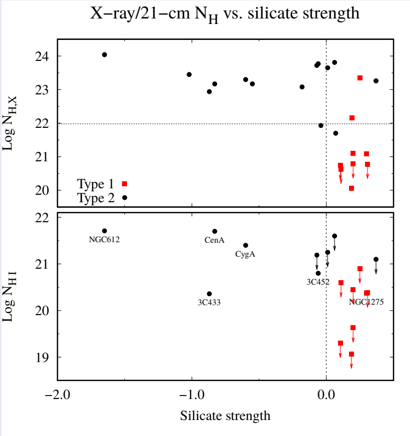


(Weedman et al. 2012)

Absorption properties

Radio/X-ray/mid-IR absorption

Sources with silicate absorption are X-ray obscured and detected at 21 cm.



Absorption properties

Radio/X-ray/mid-IR absorption

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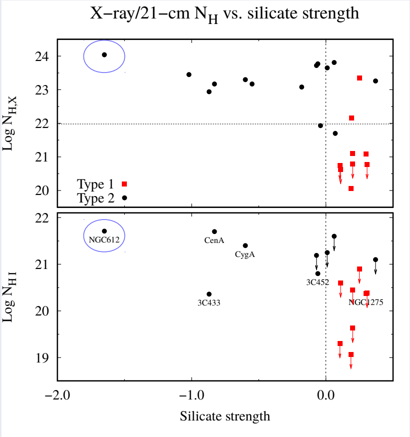
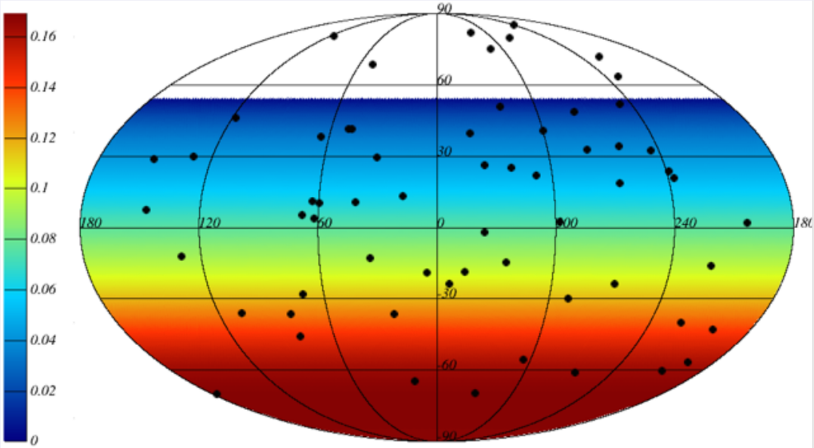
The most heavily obscured, NGC 612, has a prominent dust lane along the galaxy disc.



Neutrino detections

Collaboration with the ANTARES team (A. Coleiro, A. Kouchner).
55 objects in the FOV of ANTARES, $\sim$ 35 events expected



Conclusions

- Giant radio galaxies: X-ray properties and radio connection
  - The X-ray–radio core correlation is consistent with the efficient branch of the fundamental plane; the sources are likely powered by a radiatively efficient accretion flow.
  - In most sources, the current activity level traced by the X-ray emission is higher than expected from the radio; this is consistent with a restarting activity scenario.
- Absorption properties
  - At the zeroth order, unified models apply to radio galaxies and radio-quiet AGNs in a similar way; however, there are currently no strong evidences for heavily absorbed radio galaxies.
  - X-ray obscured sources have a higher detection fraction of 21 cm HI absorption, suggesting a link between HI and X-ray absorption structures; however, preliminary results from new GMRT observations might point to a more complex scenario.
  - Deep silicate absorption is found in a few X-ray/21 cm absorbed sources, indicating obscuration in the host galaxy.

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