Probing the efficiency of the AGN feedback in young radio sources: the case of PKS1934-63

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QUASAR mode

Rupke & Veilleux

Mrk 231

RADIO Mode

Mc Namara

Galaxy cluster MS 0735

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Models require efficiencies \( \sim 5\text{-}10\% \)

AGN feedback & Star Formation Quenching

Models require efficiencies \( \sim 5\text{-}10\% \)

Fabian 1999; di Matteo et al. 2005; Springel et al. 2005

Silk, J. + 2012

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- High Radio Power $P_{1.4\text{GHz}} > 10^{25} \text{ W/Hz}$
- Early evolutionary stages YOUNG age $10^2 - 10^5 \text{ yr}$
- Found in gas rich ETGs / merging systems
- Hosting atomic, ionised, molecular gas extreme outflows

OUR SAMPLE
PKS0023-26, PKS0252-71
PKS1814-63, PKS2135-209, 3C 459
PKS1934-63

X-Shooter
slit spectroscopy
UVB + VIS + NIR
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- $z = 0.1824$
- Radio age $\sim 1.6 \times 10^3$ yr
- Very Compact $D_{\text{radio}} \sim 130$ pc
- Very Powerful $P_{1.4\text{GHz}} = 10^{27.2}$ W/Hz

Merging

Roche+2016

Ramos Almeida+2011

Tziomis+2002

X-Shooter
4 KINEMATICAL COMPONENTS

2 Narrow

1 Broad

1 Very Broad component
4 KINEMATICAL COMPONENTS

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OUTFLOWING GAS
[OIII] line

4 KINEMATICAL COMPONENTS

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OUTFLOWING GAS

Main Goal
mass outflow rate
kinetic power
efficiency

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Models require efficiencies ~5-10% for AGN feedback & Star Formation Quenching.
Mass outflow rate

\[ \dot{M} \propto \frac{L(H\beta)}{N_e R_{out}} V_{out} \]

- H\(\beta\) Luminosity
- Gas electron density
- Outflow Velocity
- Outflow Radius

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Outflow Velocity $V_{\text{out}}$

from the kinematical model

$V_{\text{out}} = -325$ km/s
FWHM = 2090 km/s

$v_{\text{max}} = -2500$ km/s

$N_e$

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The outflow is COMPACT spatially unresolved

\( R_{\text{out}} < 1 \text{Kpc} \)

\( R_{\text{out}} > 65 \text{ pc} \)

from radio lobes separation

\( L(\text{H}\beta) \)

\( \text{N}_e \)

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Gas electron density

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Trans-auroral lines method (Holt et al. (2011))

$N_e$

Gas electron density

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Fit of the lines with the [OIII]5007Å model

$N_e$

Gas electron density
AGN photoionization models

FIX
spectral index and
photoionisation
parameter
AGN photoionization models

Fix spectral index and photoionisation parameter

Vary density and reddening

Gas electron density
Gas electron density

Narrow components $N_e \sim 10^3 \text{ cm}^{-3}$

Broad component $N_e \sim 10^{4.5} \text{ cm}^{-3}$

Very broad component $N_e \sim 10^{5.5} \text{ cm}^{-3}$

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mass outflow rate \( \dot{M} \propto \frac{L(H\beta)}{N_e R_{out}} V_{out} \)

- \( L(H\beta) \): H\(\beta\) Luminosity
- \( N_e \): Gas electron density
- \( R_{out} \): Outflow Radius
- \( V_{out} \): Outflow Velocity

Very broad component
mass outflow rates

kinetic power

efficiency

\[ E \sim M \left( v_{\text{out}}^2 + \text{FWHM}^2 \right) \]

\[ \frac{E}{L_{\text{bol}}} \]

\[ L_{\text{bol}} \sim 1.5 \times 10^{45} \text{ erg/s} \]

from \( L[\text{OIII}] \)
$0.02 \, M_{\odot}/yr < \dot{M} < 0.19 \, M_{\odot}/yr$

$5.5 \times 10^{40} \, \text{erg/s} < \dot{E} < 5.1 \times 10^{41} \, \text{erg/s}$

$3.5 \times 10^{-5} < \dot{E}/L_{\text{bol}} < 3.3 \times 10^{-4}$
$10^{-5} < \frac{E}{L_{\text{bol}}} < 10^{-4}$

5-10% for classical models

~0.5% 'multi-staged' outflows (e.g. Hopkins & Elvis 2010)

$10^{-5} - 10^{-4}$ - Kurosawa et al. (2009)

Are we missing outflowing gas? Is it a multiphase outflow?

0.01 < $M$ < 3 $M_\odot$/yr

$10^{-4} < \frac{E}{L_{\text{bol}}} < 1.5$


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multiphase outflow

NIR - H2 warm ionised gas
multiphase outflow

Ionised gas
compact outflow

atomic &
warm
molecular gas
no evident sign of
outflow

Is PKS 1934-63 too young?
multiphase outflow
... a possible scenario ...

AGN - ISM interaction ionise the gas

Cold gas forms in post-shock cooling regions
multiphase outflow

... a possible scenario ...

AGN - ISM interaction ionise the gas

Cold gas forms in post-shock cooling regions

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multiphase outflow

... a possible scenario ...

**SIMULATION**

H2 and CO start to form ~$10^5$ yr after the start of the AGN-ISM interaction (Richings & Faucher-Giguere 2017)

COMPACT RADIO SOURCES (ages $10^{2-5}$ yr) can be used to test the scenario
COMPACT RADIO SOURCES (ages $10^{2-5}$ yr) can be used to test the scenario of multiphase outflow.
multiphase outflow

COMPACT RADIO SOURCES (ages $10^{2-5}$ yr) can be used to test the scenario

PKS 1934-63 might be too young to have a cold gas outflow
Take home messages

Density is a crucial parameter to characterise outflows.

Observed outflow efficiencies are far from the 5-10% required by classical models.

Compact radio sources can test if time is the main driver to explain the multiphase outflow properties.

More results from the rest of the sample.