Cold gas reservoir feeding a distant interacting young radio galaxy

A case study from ASKAP FLASH & ALMA

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DICHOTOMY OF AGN HOST GALAXIES

INTRODUCTION
INTRODUCTION

DOES THE COLD GAS IN AGN HOSTS REFLECT THIS DICHOTOMY?

High excitation RGs:
- Radio-loud radiative mode AGN \((L_{\text{bol}} > 1\% L_{\text{Edd}})\)
- Typically central star forming hosts
- \((1+z)^3\) evolution

Low excitation RGs:
- Radio-loud jet mode AGN \((L_{\text{bol}} < 1\% L_{\text{Edd}})\)
- Typically passive hosts
- little evolution over past 10Gyrs

Pracy+ 16
INTRODUCTION

DOES THE COLD GAS TRACE SFR AND SMBH EVOLUTION?

The ratio of FIR to observed (uncorrected) FUV luminosity densities (Figure 8) as a function of redshift, using FUVLFs from Cucciati et al. (2012) and Herschel FIRLFs from Gruppioni et al. (2013). At z<2, these estimates agree reasonably well with the measurements inferred from the UV slope or from SED fitting. At z>2, the FIR/FUV estimates have large uncertainties owing to the similarly large uncertainties required to extrapolate the observed FIRLF to a total luminosity density. The values are larger than those for the UV-selected surveys, particularly when compared with the UV values extrapolated to very faint luminosities. Although galaxies with lower SFRs may have reduced extinction, purely UV-selected samples at high redshift may also be biased against dusty star-forming galaxies. As we noted above, a robust census for star-forming galaxies at z≫2 selected on the basis of dust emission alone does not exist, owing to these sensitivity limits for past and present FIR and submillimeter observatories. Accordingly, the total amount of star formation that is missed from UV surveys at such high redshifts remains uncertain.

Figure 9: The history of cosmic star formation from (top right panel) FUV, (bottom right panel) IR, and (left panel) FUV+IR rest-frame measurements. The data points with symbols are given in Table 1. All UV luminosities have been converted to instantaneous SFR densities using the factor \( K_{\text{FUV}} = 1.15 \times 10^{-28} \) (see Equation 10), valid for a Salpeter IMF. FIR luminosities (8–1,000 µm) have been converted to instantaneous SFRs using the factor \( K_{\text{IR}} = 4.5 \times 10^{-44} \) (see Equation 11), also valid for a Salpeter IMF. The solid curve in the three panels plots the best-fit SFRD in Equation 15.

These state-of-the-art surveys provide a remarkably consistent picture of the cosmic SFH: \( \psi(z) \propto (1 + z)^{-2.9} \) at \( 3 < z < 8 \), slowing and peaking at some point probably between \( z = 2 \) and \( 1.5 \), when the Universe was ∼3.5 Gyr old, followed by...
INTRODUCTION

DOES THE COLD GAS TRACE SFR AND SMBH EVOLUTION?

![Graph showing 21-cm line surveys and Lyman-α absorption](image)

- Lyman-α absorption (UV)
- Lyman-α absorption (optical)
- 21-cm line surveys
Atomic and molecular absorption lines illuminate gas on sight-line towards radio emission.

Velocity offsets from system indicative of disturbed gas associated with accretion or outflows.

Literature examples of nearby radio galaxies have found 1000km/s outflows and clouds of infalling gas.

Mostly focused on nearby, well-resolved, radio-loud AGN.
HI 21-cm absorption with the Australian SKA Pathfinder

- Wide field of view → survey many radio sources quickly
- Wide fractional bandwidth + good RFI environment → survey large redshift range
- Phased Array Feeds produce good spectral baselines for high dynamic range spectral line observations
THE FIRST LARGE ABSORPTION SURVEY IN HI

- PIs Elaine Sadler (Sydney) and James Allison (Oxford)
- 50 members, incl. Raffaella Morganti & Vanessa Moss
- All southern sky survey for HI 21-cm line absorption
- 150,000+ sight lines to extragalactic radio sources
- $0.4 < z < 1.0$ (~5 billion years of look back time)

Image credit: Vanessa Moss
ASKAP

FLASH: 25,000 POWERFUL RGs @ 0.4 < z < 1.0

Maccagni+ 17
A DISTANT YOUNG RADIO GALAXY

CASE STUDY: PKS1740-517

$t_{\text{src}} \sim 2 \text{ kyr}$

Allison+ 15; Allison+ 18 in prep.
CASE STUDY: PKS1740-517

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A DISTANT YOUNG RADIO GALAXY

ASKAP DETECTION OF HI ABSORPTION

z = 0.4

Lookback Time (Billion Years)

Absorbed Signal (percentage)

Radio Frequency (MHz)

z = 1.0

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ASSOCIATION WITH A STRONG EMISSION LINE AGN (HERG)

Blue diagram for high-z (Lamareille+ 10)

$z_{\text{sys}} = 0.4418$

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A DISTANT YOUNG RADIO GALAXY

LINE OF SIGHT COLD GAS KINEMATICS

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sources discussed by Tengstrand et al. (2009).

possibly indicating an obscured Compton-thick AGN, similar column density is consistent with that measured for other X-ray.

Figure 10.

The H I 21-cm absorption, oxygen and H compete with that seen for PKS B1607+26 (Tengstrand et al. 2009). If the observed spectrum is indeed arising from reflection of the primary continuum, then sight-lines to the AGN may instead have column densities in excess of that typical of their relatively low Galactic latitude of 1\(\degree\) (Arnaud 1996). We found that the X-ray spectra are well fit by a standard absorbed power-law model. Because of the tight constraints on the peak position due to the Galactic foreground, estimated within ±100 km s\(^{-1}\) of the rest frame defined by the systemic redshift of the galaxy (12\(\pm\)8\(\times\)10\(^5\) km s\(^{-1}\)) of the source, we used to estimate the peak location for each pixel. The profiles are plotted in the 2D spectrum. Also plotted (in black) are Gaussian fits to the profile of the cut-out. The spatial axis pixels increase in a roughly northerly direction.

Figure 11.

Top: an extract of the two-dimensional spectrum showing just the most prominent features. The red horizontal error bar indicates the uncertainty in the systemic velocity. The intrinsic spin temperature, and compare this with direct measurements of the spin temperature in other galaxies.

While the intrinsic luminosity at 4.2 keV, consistent with the disk components 1 (left) and 3 (right), which correspond to 3\(\times\)10\(^5\) cm\(^{-2}\). Using this model, we obtain an estimate of the intrinsic column density towards PKS B1740 +2\(\times\)10\(^5\) cm\(^{-2}\). Using the above best fitting model and a 1 keV normalization of 1.1\(\times\)10\(^4\) photons cm\(^{-2}\) keV, consistent with the disk components.
A DISTANT YOUNG RADIO GALAXY

GAS RESERVOIR

\[ N_{\text{HI}} = N_{\text{H}_2} \sim 10^{20} \text{ cm}^{-2} \]
\[ M_{\text{HI}} (r < 3 \text{kpc}) \sim 4.7 \times 10^6 \text{ M}_\odot \]
\[ M_{\text{H}_2} (r < 3 \text{kpc}) \sim 1.4 \times 10^7 \text{ M}_\odot \]
A DISTANT YOUNG RADIO GALAXY

FEEDING THE GAS RESERVOIR (?)

$ t_{\text{dyn}} \sim \text{few 100 Myr} $

$ t_{\text{src}} \sim 2 \text{ kyr} $

Companion (b) SFR $\sim 0.2 \, M_\odot \, \text{yr}^{-1}$

$ \Rightarrow M_{\text{stellar}} \sim \text{few } 10^9 \, M_\odot $

$ \Rightarrow M_{\text{HI+H}_2} \sim \text{few } 10^8 \, M_\odot $

Allison+ 15; Allison+ 18 in prep.
A DISTANT YOUNG RADIO GALAXY

FEEDING THE GAS RESERVOIR (?)

$t_{\text{dyn}} \sim \text{few } 100 \text{ Myr}$
$t_{\text{src}} \sim 2 \text{ kyr}$

Allison+ 15; Allison+ 18 in prep.
ASKAP FLASH survey will directly observe accreting (and outflowing) neutral gas in powerful distant radio galaxies

Test for the gas accretion mechanisms that drive the observed dichotomy in radio galaxies

ASKAP commissioning data have been used to “blindly” detect HI absorption in several distant radio galaxies, including young \( t_{\text{src}} \sim 2\text{kyr} \) PKS1740-517

Evidence of \( \sim 10^7 \, M_\odot \) HI and \( H_2 \) reservoir within 3kpc of AGN

Interaction with neighbouring star-forming companion galaxy

Evidence for further replenishment of neutral gas through tidal interaction