HI absorption towards radio AGNs of different accretion modes and redshifts

HI absorption 2018: A workshop on the status of and preparation of upcoming surveys , ASTRON, Dwingeloo

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in collaboration with

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Outline

Radio AGNs: a brief introduction

H I 21 cm absorption towards low luminosity radio AGNs of different accretion modes

H I 21cm absorption towards Compact Steep Spectrum radio AGNs at high redshift

Summary

Radio AGNs

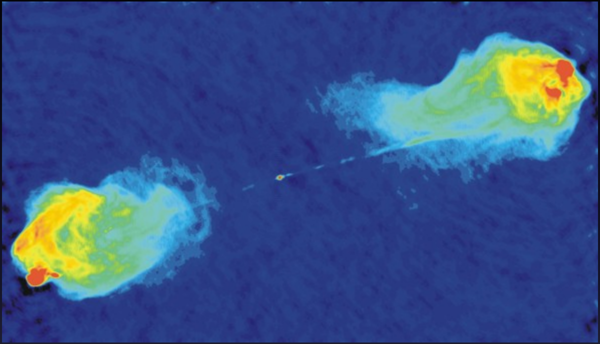


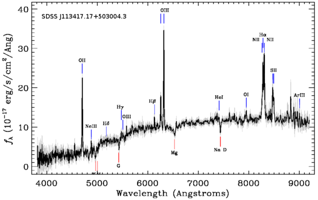
Figure: Cygnus A (R. Perley, C. Carilli & J. Dreher, ApJ, 285, L35,1984), Image courtesy of NRAO/AUI

- All massive galaxies have central supermassive black hole (Kormendy & Ho 2013).
- But not all have radio AGN activity ($P_{1.4\mathrm{GHz}} > 10^{23}$W Hz^{-1}).
- What triggers the radio AGN activity ? What are the fuelling mechanisms ? How radio sources affect their host galaxies and vice-versa ? How radio sources and their immediate environments evolve over time ?
- All these questions can be only answered by comprehensive study of radio sources, their central engines, host galaxies and environments.

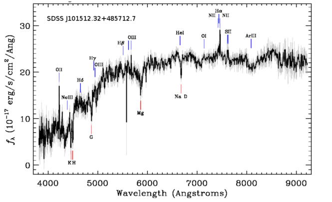
Radio AGNs: different accretion modes

Central engine and optical emission line characteristics: Shakura & Sunayev (1973), Novikov & Thorne (1973), Narayan & Yi (1994,1995), Yuan & Narayan (2014), Hine & Longair (1979), Buttiglione et al. 2010, Best & Heckman (2012), Heckman & Best (2014)

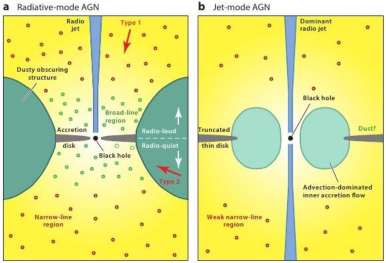
HERG: High Excitation Radio Galaxy



LERG: Low Excitation Radio Galaxy



	HERG	LERG
Optical lines	Strong emission lines	Weak emission lines
Eddington Ratio	> 1%	< 1 %
Feedback mechanism	Radiative	Jet-mode
Fueling process	Mainly mergers	Accretion of hot halo gas
Radio Luminosity	Dominant $L_{1.4GHz} > 10^{26}$ W/Hz	Mainly below 10^{26} W/Hz



Heckman & Best (2014)

Figure 3

Schematic drawings of the central engines of radiative-mode and jet-mode AGNs (not to scale).

Radio AGNs: different accretion modes

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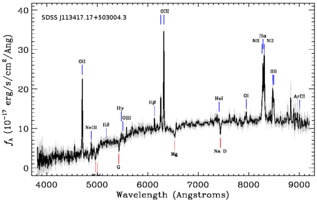

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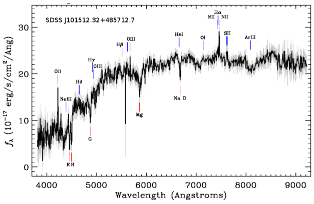

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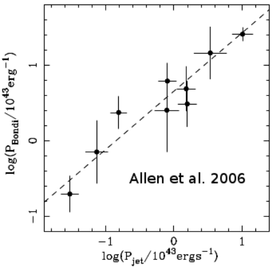

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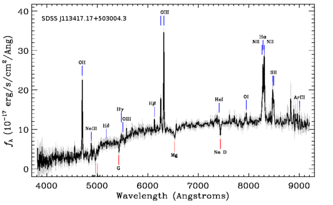

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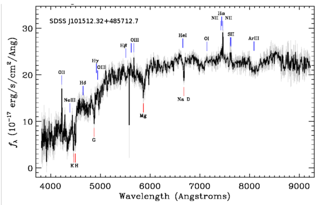

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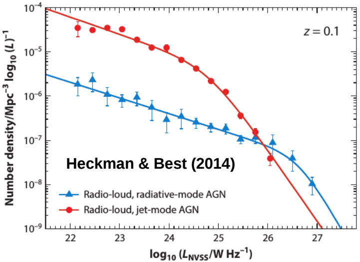
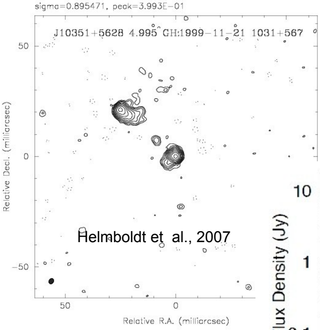


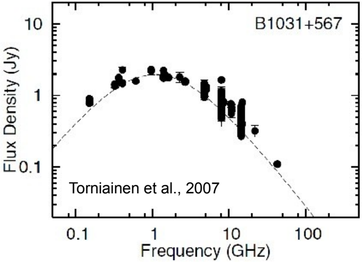
Radio AGNs: radio properties

Radio source linear sizes, spectra, luminosities and morphologies

Gigahertz Peaked Spectrum (GPS) radio sources



- Projected linear sizes < 1kpc
- Dynamical ages ~ $10^{2\text{-}3}$ yrs .
- Radio spectrum peaks at ~ 1 GHz
- VLBA image of B1031+567 (J1035+5628) ==> Compact Symmetric Objects (Wilikinson et al. 1994) morphology



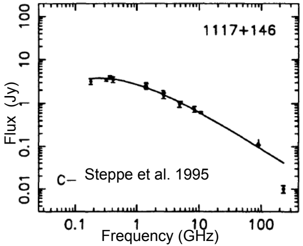
- Diverse population of radio AGNs differing in their linear sizes, spectras, luminosities and morphologies have been revealed by radio surveys and studies done at multiple scales and wavelengths !!

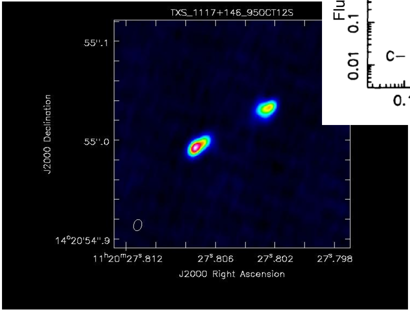
Radio AGNs: radio properties

Radio source linear sizes, spectra, luminosities and morphologies

Compact Steep Spectrum (CSS) radio sources

- Projected linear sizes 1-15 kpc
- Dynamical ages ~ $10^{3\text{-}6}$ yrs
- Radio spectrum peaks at < 500 MHz
- Spectral index steep (> 0.5) for higher frequency





VLBA image of CSS source 4C +14.41 or TXS 1117+146 at 2.3 GHz (Fey & Charlot 1997, ApJS, 111, 95); Image courtesy United States Naval Observatory (USNO) Radio Reference Frame Image Database (RRFID)

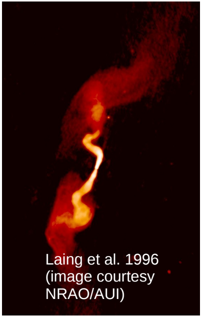
- Diverse population of radio AGNs differing in their linear sizes, spectra, luminosities and morphologies have been revealed by radio surveys and studies done at multiple scales and wavelengths !!

Radio AGNs: radio properties

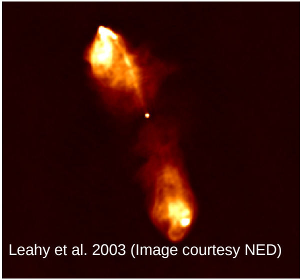
Radio source linear sizes, spectra, luminosities and morphologies

FR I radio sources

- Symmetrical radio jets which eventually expand into diffuse plumes
- Radio power 1.4 GHz < 10^{25} W/Hz
- Example: 3C31



Laing et al. 1996 (image courtesy NRAO/AUI)



Leahy et al. 2003 (Image courtesy NED)

FR II radio sources

- Have powerful collimated radio jets which eventually power lobes and hot spots.
- Radio power at 1.4 GHz > 10^{25} W/Hz
- Example: 3C98

- Diverse population of radio AGNs differing in their linear sizes, spectras, luminosities and morphologies have been revealed by radio surveys and studies done at multiple scales and wavelengths !!

Radio AGNs: radio properties

Radio source linear sizes, spectra, luminosities and morphologies

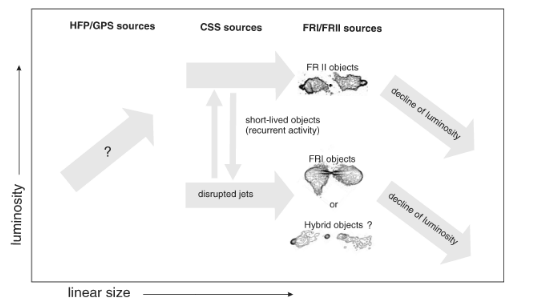


Figure 5. Evolutionary scheme of radio-loud AGNs.

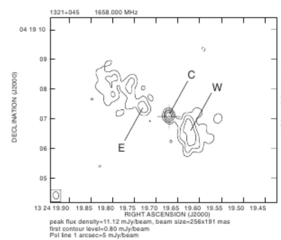
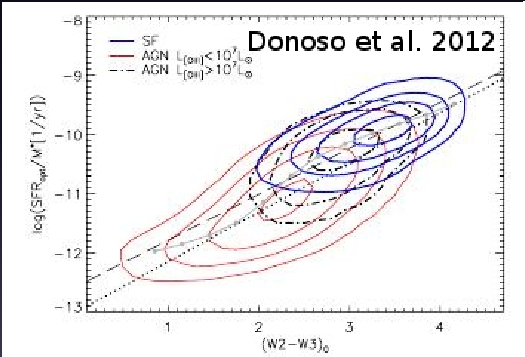


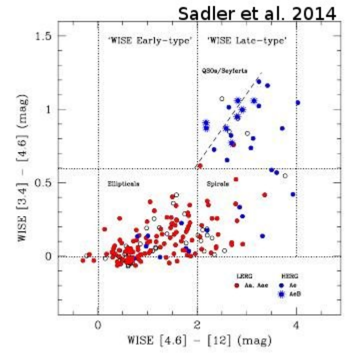
Figure: Kunert-Bazraszewska et al. 2010, MNRAS, 408, 2261

- Kunert-Bazraszewska et al. 2010 presented low luminosity ($L_{1.4\mathrm{GHz}} < 10^{26}$ W /Hz) CSS sample, mostly with disrupted jets; early stage counterpart of FR I objects ? Most of them likely to be LERGs.

Radio AGNs: different accretion modes and host galaxies

Donoso et al. (2012), Sadler et al.(2014), Pace & Salim (2016), Ellison et al. (2016)





Sadler et al. 2014; sources from AT20G-6dFGS survey at 20 GHz. W2−W3>2 : 57% HERGs W2−W3<2 : 93% LERGs.

Radio AGNs: different accretion modes and host galaxies

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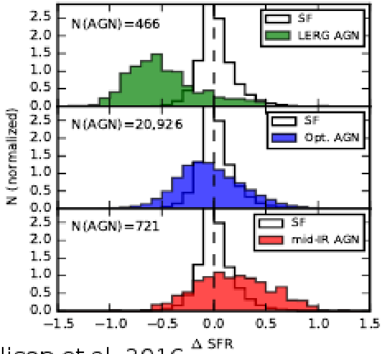

Ellison et al. 2016

- Ellison et al. 2016 compared SFR derived from total IR luminosity for LERGs, optical AGNs (using BPT diagram), mid-IR AGN (W1-W2 > 0.8) with normal SF galaxies.
- LERGs show low SFR while IR selected AGNs show slightly higher SFR as compared to SF galaxies.

Since cold gas is fuel reservoir for SF activity and HI is a tracer for cold diffuse ISM, it is important to study HI in hosts of radio AGNs of different radio properties, WISE colours and accretion modes in order to better understand the feedback and fueling processes.

HI absorption towards low luminosity radio AGNs of different accretion modes & *WISE* colours

Chandola & Saikia, 2017, MNRAS, 465, 997

How does the HI detection rate and other gas properties vary with radio source properties, host galaxy properties and central AGN characteristics?

Geréb et al. (2014, 2015): HI absorption data, radio structural classification

Best & Heckman (2012): Classification of nearby radio AGNs (FIRST radio survey) according optical emission line properties (SDSS) and excitation index (Buttiglione et al. 2010).

Cutri et al. (2013): WISE data for host galaxy property in mid-IR.

Sample: Total 100 sources. Of which 91 classified as 80 LERGs and 11 HERGs.

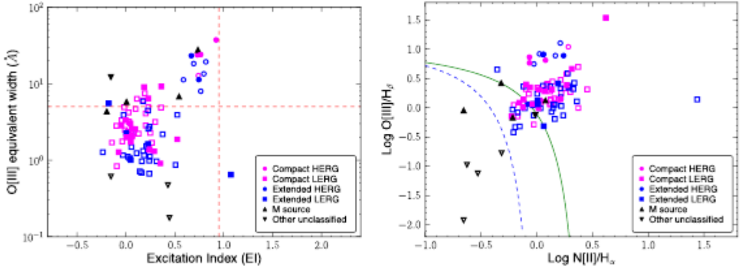

Figure 1. Left: O [III] equivalent width versus excitation index (for 91 sources with all six emission lines) with filled symbols (detections) and empty symbols (non-detections). The vertical line represents EI = 0.95, while the horizontal line is for O [III] equivalent width = 5 Å. Right: log O [III]/Hβ versus log N [II]/Hα (for 99 sources with at least four emission lines). The solid green curve is the Kewley et al. (2001, 2006) dividing line between AGNs and composite (SF+AGN) galaxies, while the dashed blue curve is the Kauffmann et al. (2003) dividing line between star-forming and composite galaxies.

HI absorption towards low luminosity radio AGNs of different accretion modes & *WISE* colours

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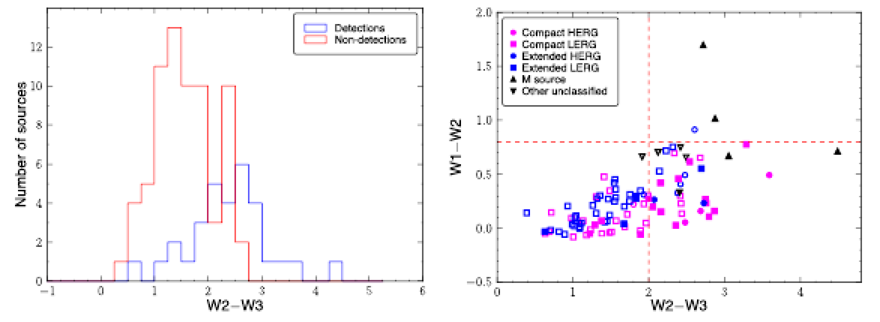
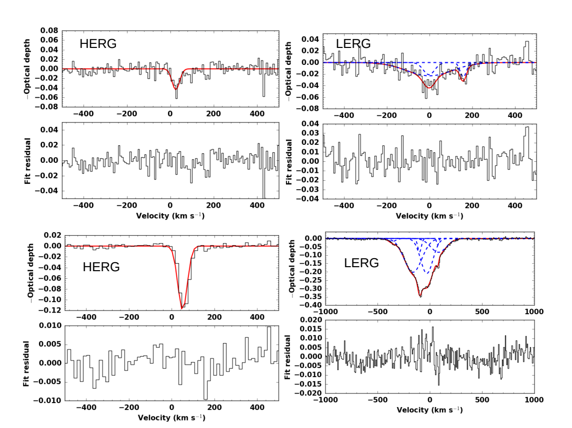


- Detection rates: HERG (5/11; 45.5 ± 20.3 %), LERG (21/80; 26.3±5.7%)
- Although there is a suggestion of higher detection rates for HERGs, statistical errors are also high due to small numbers.
- Strong dependence of detection rate on WISE W2-W3 colour. Sources with compact radio size and W2−W3 >2 have highest detection rate!
- Detection rate for W2−W3 > 2, LERGs (13/21; 61.9±17.2%), HERGs (5/9; 55.6±24.8%).

HI absorption towards radio AGNs of different accretion modes

Chandola Y., Saikia D.J., Li Di (in prep.)



- Observations towards 28 radio AGNs WISE colour W2−W3 >2 (14 HERGs & 14 LERGs) using the GMRT; z < 0.3.
- HI absorption detection towards 8 radio AGNs from the 20 processed (40 % detection). Of these 8, 7 are new detections. 4 of these new detections need to be confirmed with more sensitive observations. Detection rate: HERGs 3/8, LERGs 5/12.
- All 3 HI absorption detections towards HERGs are narrow (FWHM < 100 km s^{-1}) and close to optical redshift. LERGs have complex and wider profiles » jet-cloud interactions ??

HI absorption towards radio AGNs of different accretion modes

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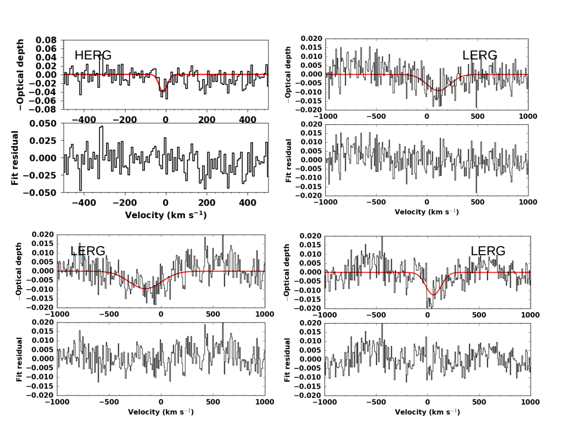

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HI 21cm absorption towards Compact Steep Spectrum radio AGNs at high redshift

Chandola Y. & J.N.H.S. Aditya (work in progress)

- Star formation and AGN activity peak at redshift around 2, and decrease thereafter (Heckman & Best 2014).
- Studying redshift evolution in properties of associated HI gas in radio AGNs is important in order to fully understand the hostgalaxy-radio AGN co evolution with redshift.
- Many HI absorption studies for z $<$ 1; more than 400; around $\sim$ 90 till recently for z $>$ 1 and only 7 detections.
- CSS objects can be used to probe the HI gas properties (e.g. integrated optical depth) in host galaxy ISM and its evolution with redshift.

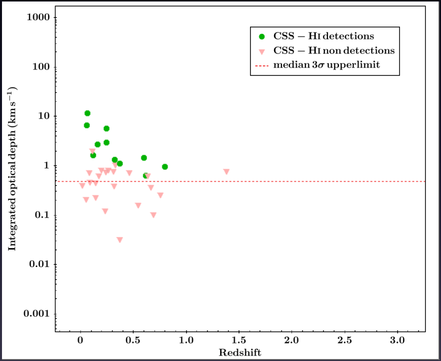

Figure: HI integrated optical depth (HI detections) and 3σ upper limits (HI non-detections) for 34 CSS sources from Gupta et al. (2006)

HI 21cm absorption towards Compact Steep Spectrum radio AGNs at high redshift

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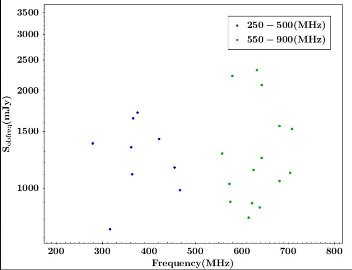
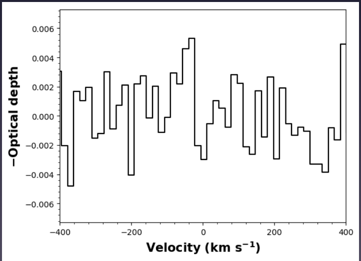


Figure: Flux values at observing frequencies vs. observing frequencies for high redshift CSS sample.

- Sample of 24 CSS objects (z >1) observed with the GMRT in May 2018.
- All sources flux densities $\gtrsim$ 200 mJy at 1.4 GHz.
- $S_{\mathrm{obfreq}} \sim S_{1.4\mathrm{GHz}}(\nu_{\mathrm{obfreq}}/1400)^{-0.7}$

- Data reduction in progress.
- For a CSS object at z=1.478 (observing frequency $\sim$ 572.9 MHz)and peak continuum flux density 941.4 mJy/beam, HI absorption spectra with τ_{rms} $\sim$0.0024 ; velocity resolution $\sim$17 km s^{-1}.
- 3 σ upper limit on integrated optical depth is $\sim$ 0.48 km s^{-1} (assuming line with Gaussian profile FWHM =100 kms^{-1})



HI absorption surveys with SKA pathfinders

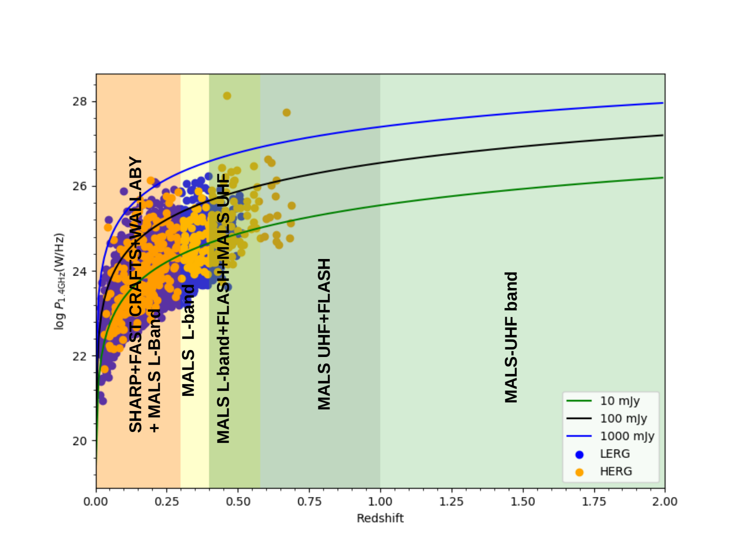


Figure: log Luminosity (1.4 GHz) vs. redshift plot and different HI absorption surveys. Sources classified as LERGs and HERGs by Best & Heckman (2012) are shown in the plot.

Summary

- We observed 28 mid-IR bright (W2−W3>2 mag.) low radio luminosity radio AGNs (14 LERGs & 14 HERGs) with the GMRT for HI 21 cm absorption in order to understand the differences in gas properties in different accretion modes.
- Over all we have 7 new HI absorption detections from 20 analysed.
- We find that detection rates are similar for two types of AGNs for similar mid-IR colours of host galaxies.
- All 3 HERGs have narrow HI line profiles closer to optical systemic velocity while LERGs have complex and wider profiles.
- In another project, we are studying HI absorption towards compact steep spectrum radio AGNs at high redshifts. From the very preliminary data reduction, we do not have any new HI detection.
- Future HI absorption surveys, along with sensitive optical spectroscopic studies will be useful to further understand the differences in HI gas properties of different accretion mode radio AGNs.

Thanks for your attention !! Comments and suggestions are welcome !!