HI absorption towards the radio galaxies & FAST HI sciences

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Outline

1. HI absorption towards the radio galaxies
   - Introduction
   - Circumnuclear HI gas properties and radio source luminosity
   - Associated HI absorption studies and future surveys

2. FAST HI sciences
   - Introducing FAST
   - FAST HI sciences

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Circumnuclear Gas in Radio Galaxy Hosts

- It is very important to study kinematics & distribution of cold neutral gas in central regions of active galaxies.
- ✓ to understand triggering of AGN[talk by Filippo Maccagni] & fueling process.
- ✓ to understand mechanical feedback from AGN due to jet-cloud interaction which can have significant effects on **S**tar **F**ormation **R**ate [talk by Raffaella Morganti].
- ✓ to find evidence of dusty torus, and AGN unification scheme[Gupta & Saikia 2006].
- ✓ to know the reason behind episodic activities in some AGNs[Chandola et al. 2010, Salter et al. 2010, Shuvleski et al. 2012 and references therein].

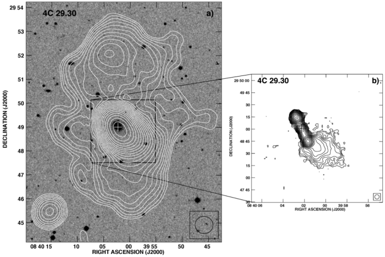

Figure: Collage reproduced from Jamrozy et al. 2007

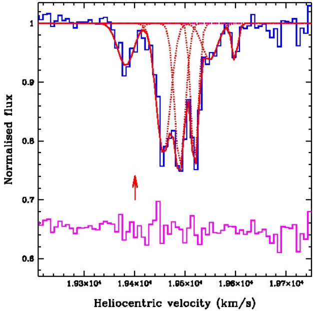

Figure: HI absorption spectra towards the 4C 29.30 core Chandola, Saikia & Gupta (2010)

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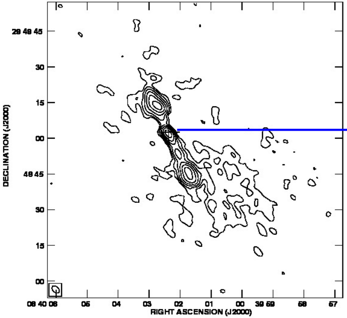

Figure: GMRT 4C 29.30 map at 1332 MHz from Chandola, Saikia & Gupta (2010)

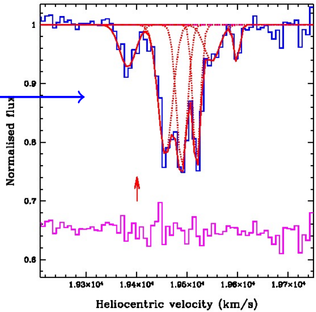

Figure: HI absorption spectra towards the 4C 29.30 core Chandola, Saikia & Gupta (2010)

Circumnuclear HI gas properties and radio source luminosity

- Different mechanisms for fuel transport in different luminosity AGNs:
  - ✓ galaxy-galaxy interaction (Heckman et al. 1986)
  - ✓ large scale bars or turbuelence in ISM (Shlosman, Frank & Begelman 1989)
  - ✓ accretion of circumgalatic hot gas (Best et al. 2006).
- Low luminosity FR I radio sources may have geometrically thin torus/ HI disc (Morganti et al. 2001)
- **Chandola, Sirothia & Saikia, 2011, MNRAS, 418, 1787** have done HI studies towards low luminosity compact nearby radio sources, in order to compare properties of HI gas associated with different luminosity radio sources at early stage of radio source evolution.
- Earlier studies such as Pilhström, Conway & Vermeulen (2003), Vermeulen et al. (2003) & Gupta et al. (2006) have majority of their HI studies done towards high luminosity radio sources.
- Sample of 18 sources known as CORALz (**CO**mpact **RA**dio sources **A**t **L**ow red-shift) core sample by Snellen et al. (2004) has following characteristics:
  - $S_{1.4GHz}$>100mJy.
  - Angular size <2 arcsec.
  - Red-shift range 0.024-0.152.
  - ∼100 times weaker than those studied by Gupta et al. 2006.
- Observations were done with the GMRT during Dec. 2009 - Feb. 2010; Bandwidth 4 MHz (∼ 900 km/s); Velocity resolution ∼7 km/s.

Results:detections

- **New HI absorption detections towards 7 sources**.
- **The column densities range: $\sim 1.78 \times 10^{20}$ to 10^{22} cm^{-2} Median value of $\sim 7\times10^{20}$cm^{-2}. The more luminous GPS & CSS objects the median value is $\sim 5\times10^{20}$cm^{-2}**.
- **The upper limits for non-detections range from $\sim$0.9 to $\sim$ 4.2 $\times 10^{20}$cm^{-2}**.

J150805+342323

- ΔI_{rms}=0.95 mJy/beam/ch
  I_c = 134 mJy
  τ_{rms} =0.007
  N(HI)=125$\times 10^{20}$ cm^{-2}
  z= 0.0456
  Three blue shifted components possibly due to jet-cloud interactions
- CSS object
  CO emission detected (Mazarella et al. 1993, Evans et al. 2005)

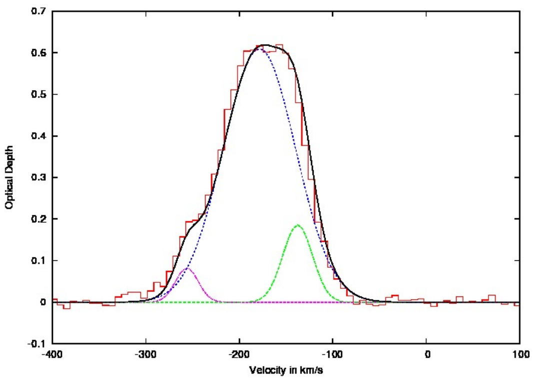

Figure: HI spectra towards J150805+342323
Chandola, Sirothia & Saikia, 2011, MNRAS, 418, 1787

Com. No.	Vel. km s^{-1}	FWHM km s^{-1}	τ_p	N(HI) 10^{20} cm^{-2}
1	−256.1(1.4)	28.8(3.6)	0.0822(0.0083)	4.56(1.04)
2	−178.4(1.1)	91.1(1.7)	0.6100(0.0084)	107.20(3.46)
3	−137.5(0.9)	37.4(3.1)	0.1862(0.0178)	13.42(2.39)

Detection rates

- Earlier HI absorption studies towards high luminosity compact radio sources (Pihlström et al. 2003, Vermeulen et al. 2003, Gupta et al. 2006) have reported higher detection rate towards GPS sources than CSS sources.
- In our studies towards low luminosity compact radio sources also, we find higher detection rate towards (3/6) GPS sources than (4/11) CSS sources. Although statistical uncertainities in our case are large due to small sample.

HI column density vs. linear size

- Anti-correlation between HI column density & linear size (Pihlström et al. 2003, Gupta et al. 2006) for higher luminosity CSS & GPS objects is also consistent for lower luminosity radio sources.
- Pihlström et al. 2003: radial density profile with a disk geometry; Curran et al. 2013: N(HI) derived from $\tau_{obs} \propto f \propto 1/d_{em}$.

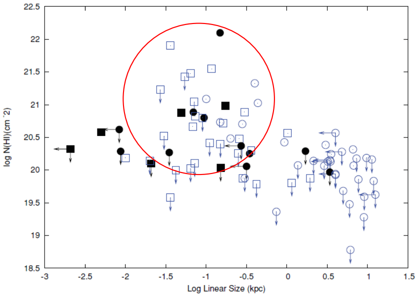

Figure: ⊡ ⊙ **from Gupta et al. 2006**;■ • **our observations**; circles: CSS objects; squares: GPS objects ; arrows denote upper limits
Chandola, Sirothia & Saikia, 2011, MNRAS, 418, 1787

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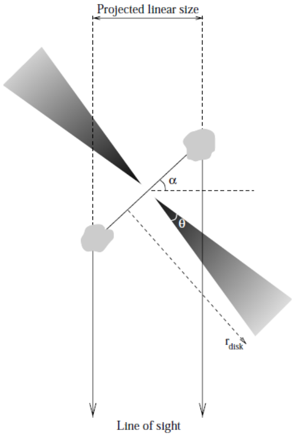

Conclusions, follow up and future

- We reported new detections of HI absorption towards 7 sources.
- Within statistical uncertainities, detection rates similar to higher luminosity sources; consistent with anti-correlation.
- Although the number of lower luminosity sources and sensitivity of observations need to be increased, our observations suggests that low velocity blue-shifted feature could be due to low power jets.
- Follow up:
  - Arecibo observations towards J1409+3604 & J1508+3423 to look for HI emission to study global properties.
  - GMRT proposal to large scale HI gas in emission towards 7 sources with HI absorption.
  - High resolution VLBI observations to know precisely the location of absorbing gas.

- Present studies limited to small samples of low luminosity sources due to sensitivity of current radio telescopes.
- Future surveys with telescopes with higher sensitivity like FAST, ASKAP, MeerKAT, SKA, LOFAR will be useful.

Associated HI absorption studies and future surveys

- HI absorption towards cores of larger radio sources: Any difference in circumnuclear HI gas properties as radio source evolve ? (Chandola, Gupta, & Saikia, 2013); similar sensitivity samples; higher detection rate towards CSS & GPS objects; larger radio sources weaker core; sample smaller than CSS & GPS objects; larger statistical uncertainities.
- Rejuvenated radio sources: higher trend of HI absorption detection (Saikia & Jamrozy, 2009); again limitation due to weaker core.
- Future HI surveys with higher resolution and sensitivity telescopes like SKA, ASKAP, MeerKAT useful e.g. FLASH survey, talk by Elaine Sadler.
- Find relic emission around GPS & CSS sources detected with HI absorption; GMRT observation in 2012 for 7 GPS sources from Gupta et al. (2006); Study larger number of sources with sensitive telescopes like LOFAR.
- Lower HI detection rates at higher red-shift (Curran et al. 2013 and references therein); B2 0902+34 (z=3.398, Uson et al. 1991); sensitivity one of the possible reason ?
- Stacking techniques useful to reach lower optical depth talk by Kantinka Gereb.

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FAST: Five hundred metre Aperture Spherical radio Telescope

- Arecibo type; Dawodang karst depression in Guizhou, China, $25^\circ 48^{'}$N, $107^\circ 21^{'}$E; large enough to host 500 m telescope; deep to allow a zenith angle of 40 degrees.
- Work commenced in March of 2011; expected to be completed in 2016.
- Active reflector; wide band; light-weight feed cabin.
- Freq. range 70 MHz-3 GHz; Sensitivity (L-band): A/T $\sim$2000 ; System Temp. $\sim$20K; Resolution (L-band): 2.9'; Multi-beam (L-band) $\sim$ 19 beams; Slewing time : $<$10 minutes; Pointing accuracy: $8^{''}$

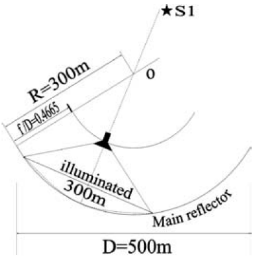

Figure: Left: FAST optical geometry; Right: FAST model (Rendong Nan et al. 2011)

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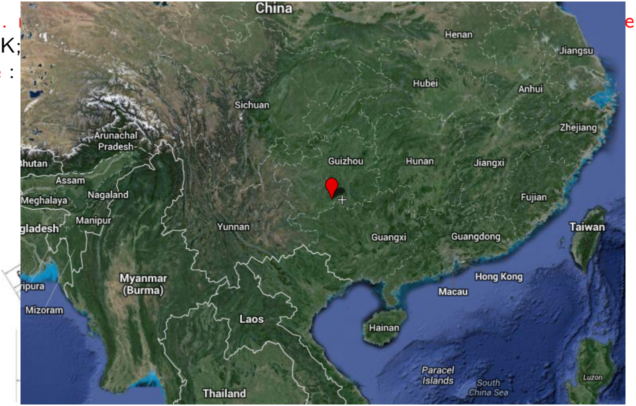

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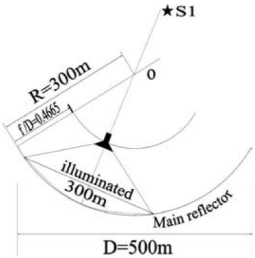

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FAST: The Milky way ISM

- HI Self-Absorption (HISA) and HI Narrow Self-Absorption (HINSA): dark molecular clouds, FAST good collecting area, wide band ∼ 1000 km/s, velocity resolutin better than 0.1 km/s ($\Delta\nu \sim 0.5$ kHz), very narrow lines.
- FAST HI surveys and ISM Galactic surveys of 21 cm line , 19 beam-L band focal plane array, FAST 5 times faster than Arecibo in mapping Galactic HI, ∼ 30% better angular resolution & can observe 2-3 times more sky than Arecibo.

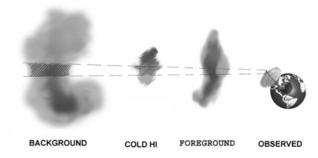


Figure: HINSA radiative transfer (Di Li & P.F. Goldsmith, 2003, ApJ, 585, 823)

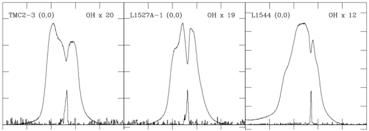


Figure: HINSA spectra (Di Li & P.F. Goldsmith, 2003, ApJ, 585, 823)

FAST: HI in external galaxies

- Probe faint end of the HI mass function in the very local universe.
- Investigate the extent of HI disk; extend rotation curve to unprecedented distance.
- Detect Cold Dark matter satellites and possible HI companion.
- Determine the populations of the High Velocity Clouds around other galaxies.
- FAST with its wide band and high sensitivity can be ideal instrument to study high velocity outflows in radio galaxy hosts.

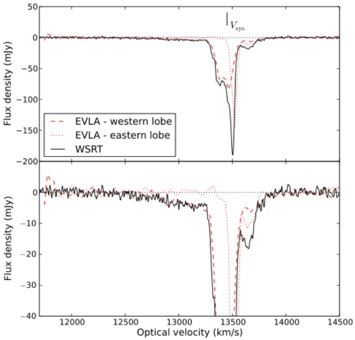


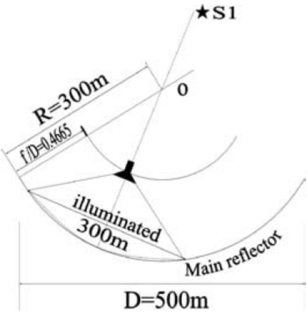
Figure: 3C293 EVLA and WSRT HI absorption spectrum from Mahony et al. 2013

FAST: HI in cosmology

- Test the validity of ΛCDM simulations
  -structure compared with observed matter; no. of observed low mass haloes much less than predicted by simulations "missing satellite problem"
- High sensitivity and multibeam enables FAST to slice the matter power spectrum
  - survey large number of galaxies in a large volume; 1 hr RFI free observation; galaxies with $M_{HI} \sim 10^{10} M_{\odot}$ can be detected out to redshift of 0.7.
  - blind survey mode and 6000s integration per field, FAST expect to detect 42,000 galaxies with $< z > \sim 0.3$ in 30 days.
- HI power vs. red-shift for studying galaxy evolution

FAST: VLBI

- Image sensitivity of VLBA (L-band) $\sim$ 80 μJy/beam
- VLBA+Effelesberg+GBT+VLA image senisitivity $\sim$ 5.5 μJy/beam.
- Replacing Arecibo with FAST, sensitivity $\sim$3.1μJy/beam



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Summary

- Surveys with better sensitivity, stable band and resolution required to explore more about associated HI absorption.
- FAST with its faster survey speed, wide band and sensitivity will be ideal instrument for future surveys.

Thank you !!!