Distribution of cold H I gas around galaxies

H I Absorption Workshop 2017, ASTRON

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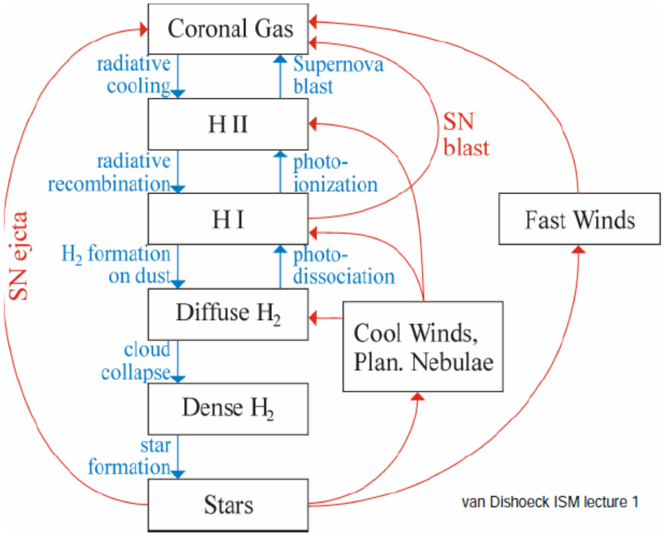
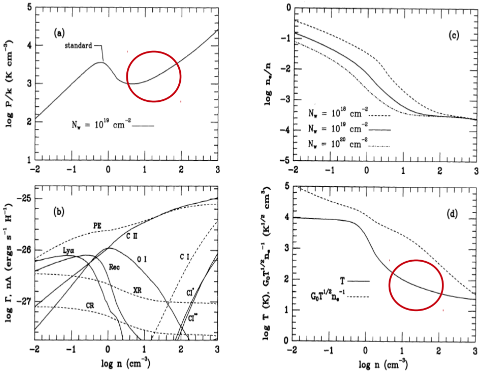
Interplay between ISM phases and star formation



Cold Neutral Medium (CNM)



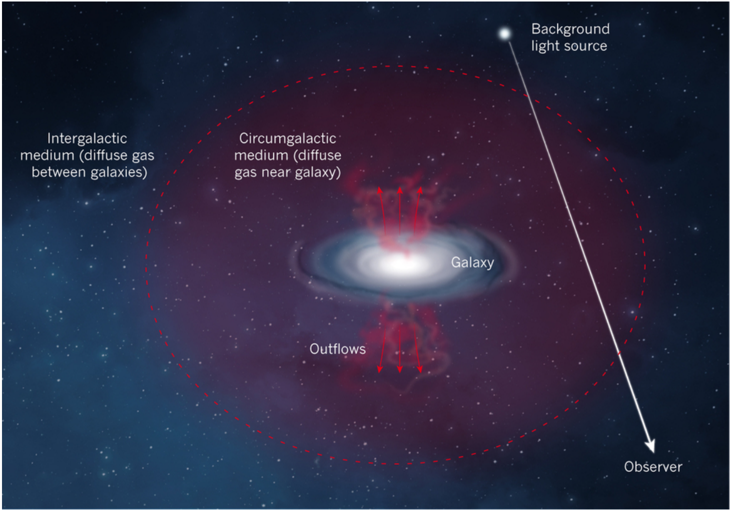
	Diffuse Atomic	Diffuse Molecular	Translucent	Dense Molecular
Defining Characteristic	$f^n_{H_2} < 0.1$	$f^n_{H_2} > 0.1$ $f^n_{C+} > 0.5$	$f^n_{C+} < 0.5$ $f^n_{CO} < 0.9$	$f^n_{CO} > 0.9$
A_V (min.)	0	~0.2	~1–2	~5–10
Typ. n_H (cm^{-3})	10–100	100–500	500–5000?	$>10^4$
Typ. T (K)	30–100	30–100	15–50?	10–50
Observational Techniques	UV/Vis H I 21-cm	UV/Vis IR abs mm abs	Vis (UV?) IR abs mm abs/em	IR abs mm em

Wolfire+ 1995, Snow & McCall 2006

Outline

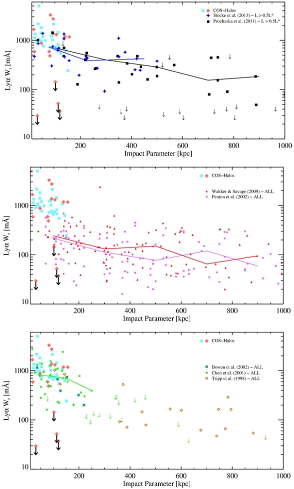
1. H I 21-cm absorption survey of $z < 0.4$ galaxy-selected sample
2. H I 21-cm absorption survey of $0.5 < z < 1.5$ absorption-selected sample

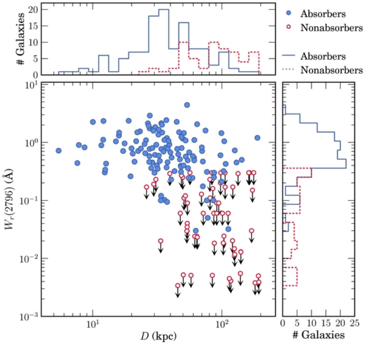
Quasar-galaxy-pairs (QGPs)



Peeples 2015

Mapping gas around galaxies using absorption





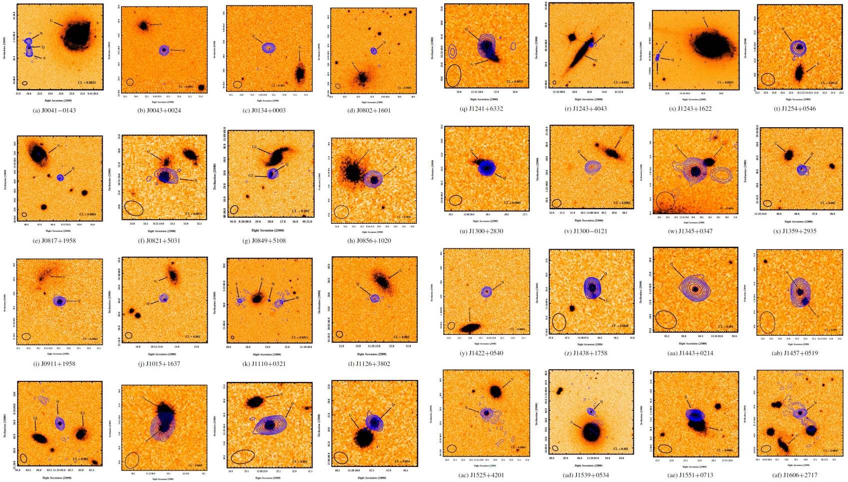
Tumlinson+ 2013, Nielsen+ 2013

Sample of $z < 0.4$ QGPs

- Sample built from SDSS and FIRST (45 QGPs in statistical sample)
- Combined with literature data

  (e.g. Carilli & van Gorkom 1992; Borthakur+ 2010, 2016; Reeves+ 2015, 2016; Zwaan+ 2015)
- 69 radio sightlines probing 64 galaxies over $b \sim 0 - 35$ kpc
- Radio data: ∼400 hrs of GMRT, VLA, WSRT
- Optical data: SDSS, SALT
- Median: $b = 15$ kpc, $z = 0.1$, $M_* = 10^{10} M_\odot$, $L_B = 10^{10} L_\odot$
- 3σ N(H I) sensitivity $\leq 5 \times 10^{19}$ cm^{-2} for 100 K gas

Sample of $z < 0.4$ QGPs



(a) J0041−0143 (b) J0043+0024 (c) J0134+0003 (d) J0802+1601 (q) J1241+6332 (r) J1243+4043 (s) J1243+1622 (t) J1254+0546

(e) J0817+1958 (f) J0821+5031 (g) J0849+5108 (h) J0856+1020 (u) J1300+2830 (v) J1300−0121 (w) J1345+0347 (x) J1359+2935

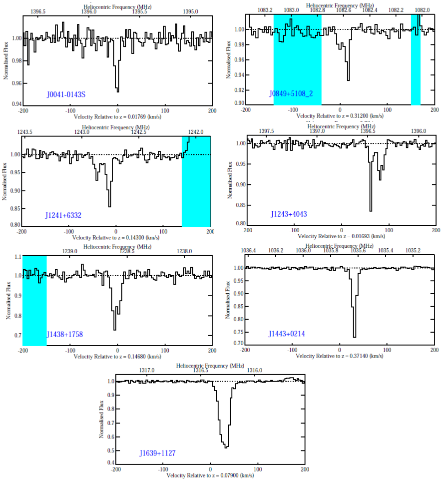
(i) J0911+1958 (j) J1015+1637 (k) J1110+0321 (l) J1126+3802 (y) J1422+0540 (z) J1438+1758 (aa) J1443+0214 (ab) J1457+0519

(m) J1133+0015 (n) J1156+3412 (o) J1209+4119 (p) J1228+3706 (ac) J1525+4201 (ad) J1539+0534 (ae) J1551+0713 (af) J1606+2717

Dutta+ 2017a, MNRAS, 465, 588

Sample of $z < 0.4$ QGPs

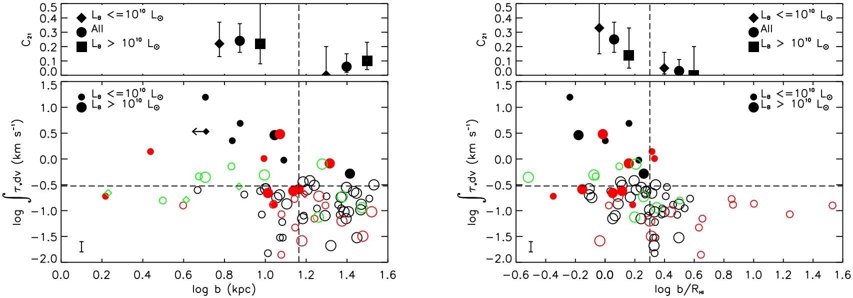
Our survey has resulted in seven H I 21-cm detections



Gupta+ 2010, 2013; Srianand+ 2013; Dutta+ 2016, 2017a

Radial profile of cold H I gas around $z < 0.4$ galaxies

H I 21-cm absorption strength ($\int \tau dv$) and covering factor (C_{21}) show weak declining trend with impact parameter and radial distance

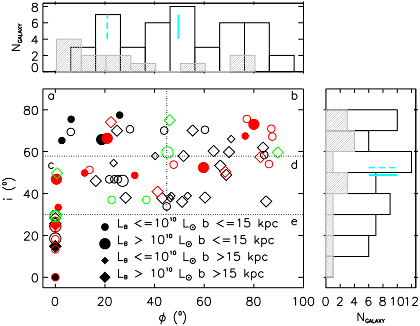


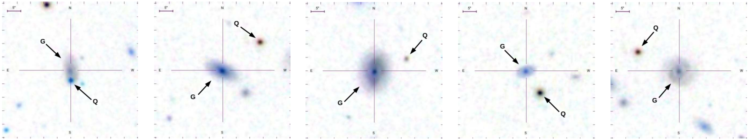
Dutta+ 2017a, MNRAS, 465, 588

No significant dependence of $\int \tau dv$ and C_{21} on host galaxy properties, i.e. luminosity, stellar mass, colour, Σ_{SFR}

Azimuthal profile of cold H I gas around $z < 0.4$ galaxies

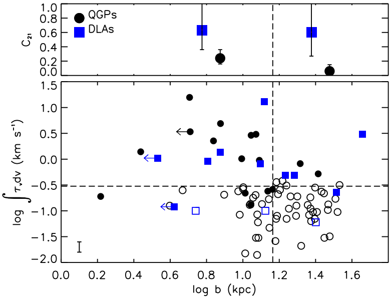
$\int \tau dv$ and C_{21} show weak dependence on galaxy orientation, with tentative indication for most H I 21-cm absorbers to be co-planar with H I disks





Nature of cold H I gas around $z < 0.4$ galaxies

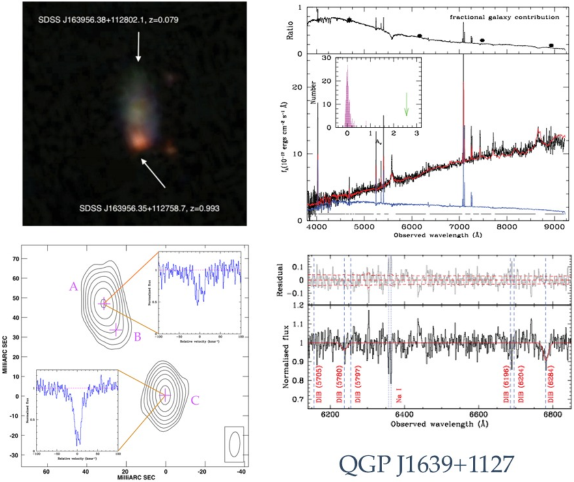
Incidence of H I 21-cm absorption is ∼4 times higher in $z < 1$ DLAs compared to low-z QGPs, indicating small size (parsec-scale) of cold gas clouds



Dutta+ 2017a, MNRAS, 465, 588

H I gas distribution around low-z galaxies that can contribute to DLA population is patchy (∼30% covering factor within ∼30 kpc), and ∼60% of DLAs have cold gas that can produce detectable H I 21-cm absorption

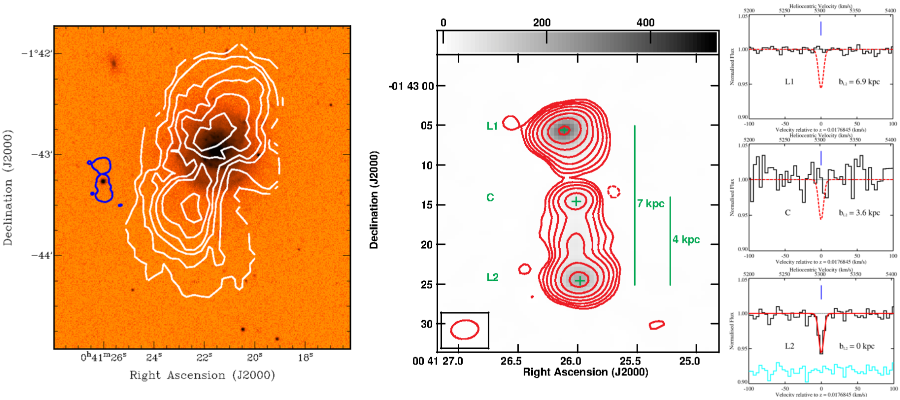
Parsec-scale structures in H I gas



QGP J1639+1127

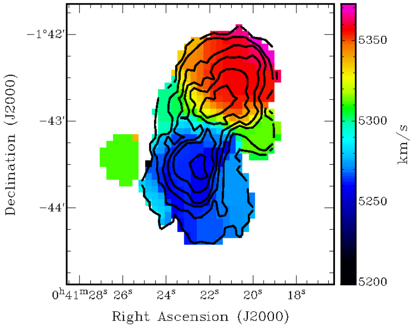
Srianand+ 2013

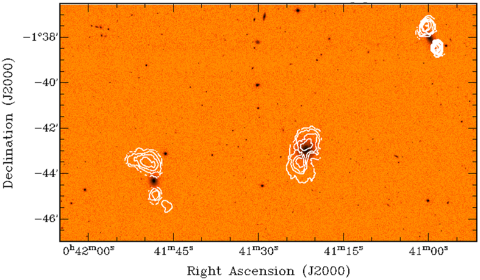
Kiloparsec-scale structures in H I gas



Dutta+ 2016, MNRAS, 456, 4209

Kiloparsec-scale structures in H I gas

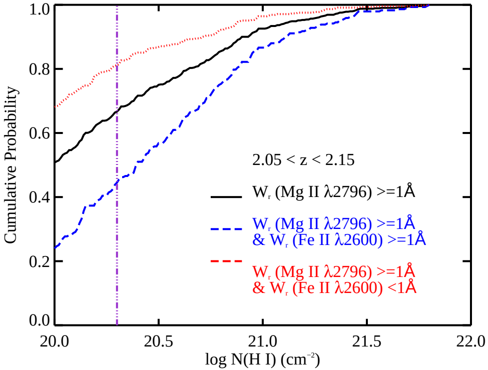




Dutta+ 2016, MNRAS, 456, 4209

Probing galaxies at high-z via strong Fe II absorption

Strong Mg II/Fe II systems have high probability of detecting high N(H I) gas

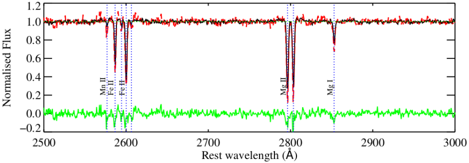


H I 21-cm absorption search in 16 strong Fe II systems at $0.5 < z < 1.5$
+ 30 systems from literature *(Gupta+09, Gupta+12)* $\rightarrow$
Incidence of H I 21-cm absorption increases with strength of Fe II absorption

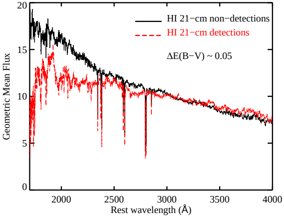
Dutta+ 2017b, MNRAS, 465, 4249

Cold gas, metal and dust content

H I 21-cm absorption arises on an average in systems with stronger metal absorption



Quasars with H I 21-cm absorption detected towards them are more reddened



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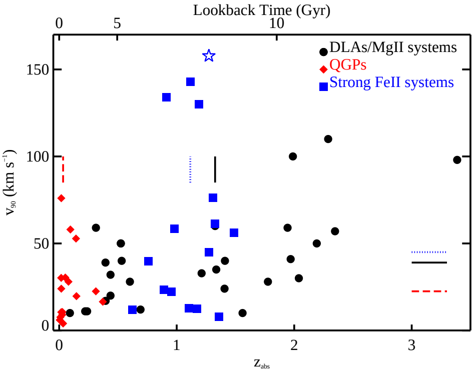
Redshift evolution of H I 21-cm absorbers

Velocity width of H I 21-cm absorption lines show an increasing trend with redshift

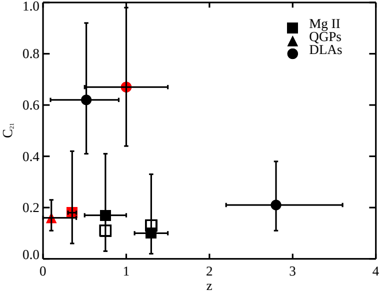


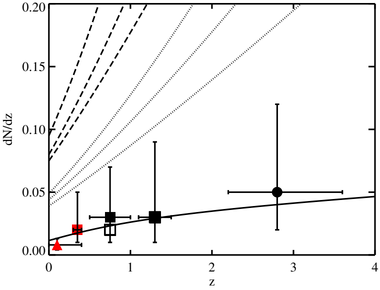
H I 21-cm absorbers could be arising from more massive galaxy halos at high-z

Dutta+ 2017b, MNRAS, 465, 4249

Redshift evolution of H I 21-cm absorbers

Cold gas fraction in DLAs may have an increased by factor of 3 from $z > 2$ to $z < 1$





Interpretation of cold gas evolution limited by large uncertainties and systematics

Gupta+ 2012, Srianand+ 2012, Kanekar+ 2014, Dutta+ 2017a,b,c

Science with SKA Pathfinders

Upcoming blind H I 21-cm absorption line surveys (MALS, SHARP, FLASH) will provide accurate and uniform measurement of the redshift evolution of the cold gas cross-section in $z < 1.5$ *galaxies in a dust- and luminosity-unbiased way*

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- Caution is needed in interpreting the distribution and structure of cold gas around galaxies
- Multi-wavelength follow-ups and joint H I 21-cm emission and absorption studies of QGPs essential
- Comparison of blind and absorption-selected searches at high redshift
- Upcoming surveys could unravel a new population of dusty absorbers towards highly reddened quasars

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THANKS!