21-cm Absorption in Damped Lyman-α Systems

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Abstract

Damped Lyman-α Systems (DLAs) are high column density absorbing clouds lying along the line-of-sights to distant quasars. DLAs constitute a large sample (>150) of high column density optical absorbers at known redshifts, making them excellent probes of the early Universe, particularly through the cold neutral atomic gas as traced by the HI 21-cm spin-flip transition. However, only 50% of the 35 systems deeply searched are known to absorb in 21-cm, most of which occur at low redshift (z < 1) and all below z=2. Through a detailed analysis of the literature, we find that the likelihood of detecting 21 cm in DLAs may be subject to certain selection effects. Here we discuss how the non-detections may be due to geometrical effects along the line-of-sight to the background continuum source (radio quasar), rather than the traditional view that this is the cause of large spin (≈ kinetic) temperatures in the absorbing clouds of the intermediate absorber (DLA). Lowering the estimates of spin temperature values in DLAs would bring these closer to those in nearby spirals (≲ 300 K), while suggesting smaller extents for the absorbing regions.

The spin temperature is defined via the observed velocity integrated optical depth, of the HI line which the traces *cold* neutral gas:

$$T_{spin} \equiv f.\,N_{HI} / (1.8 \times 10^{18} . \int \tau\, dv) \approx T_{kin}$$

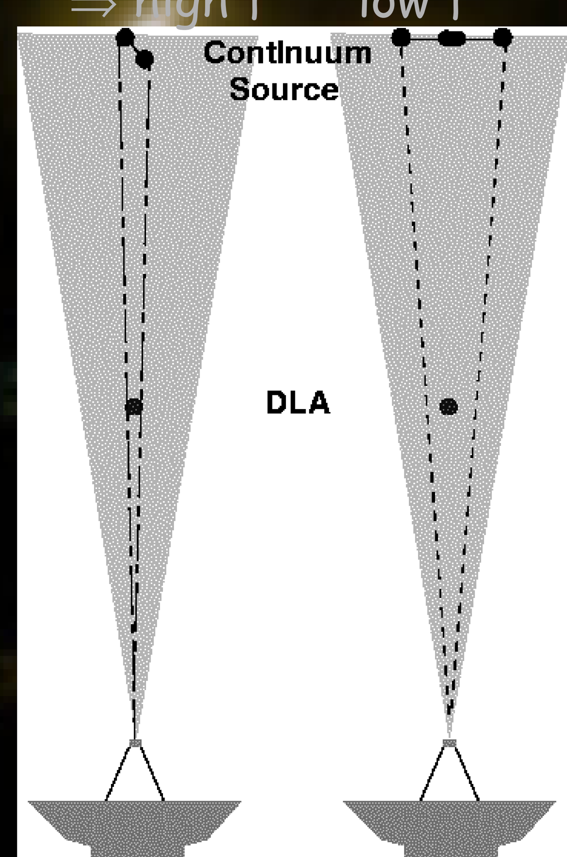
Neutral hydrogen column density (warm & cold), from Ly-α line

Non-detections due to high T_{spin} or low covering factor, f

Usually attributed to high T_{spin} although we have reservations...

1. Higher HI detection rates known in compact radio quasar hosts
2. f =1 usually assumed. At best f is estimated by comparing VLBI core flux with total flux - no information on size of the absorbing region
3. T_{spin} ranges from 20 to > 9000 K
4. No apparent relation between estimates of T_{spin} and line-width
5. H_2 in Q 0528-020 gives T_{kin}~ 200 K cf. T_{spin} > 700 K from a non-detection for 21-cm absorption

Compact Extended
continuum source
⇒ high f low f



Generally accepted current consensus

- Low redshift - approximately equal numbers of detections and non- detections ⇒ mix of low and high spin temperatures
- High redshift – almost all non-detections ⇒ high spin temps

⇒ Mix of large and compact galaxies at low z
Compact galaxies dominate at high z

HOWEVER, WE FIND THAT…

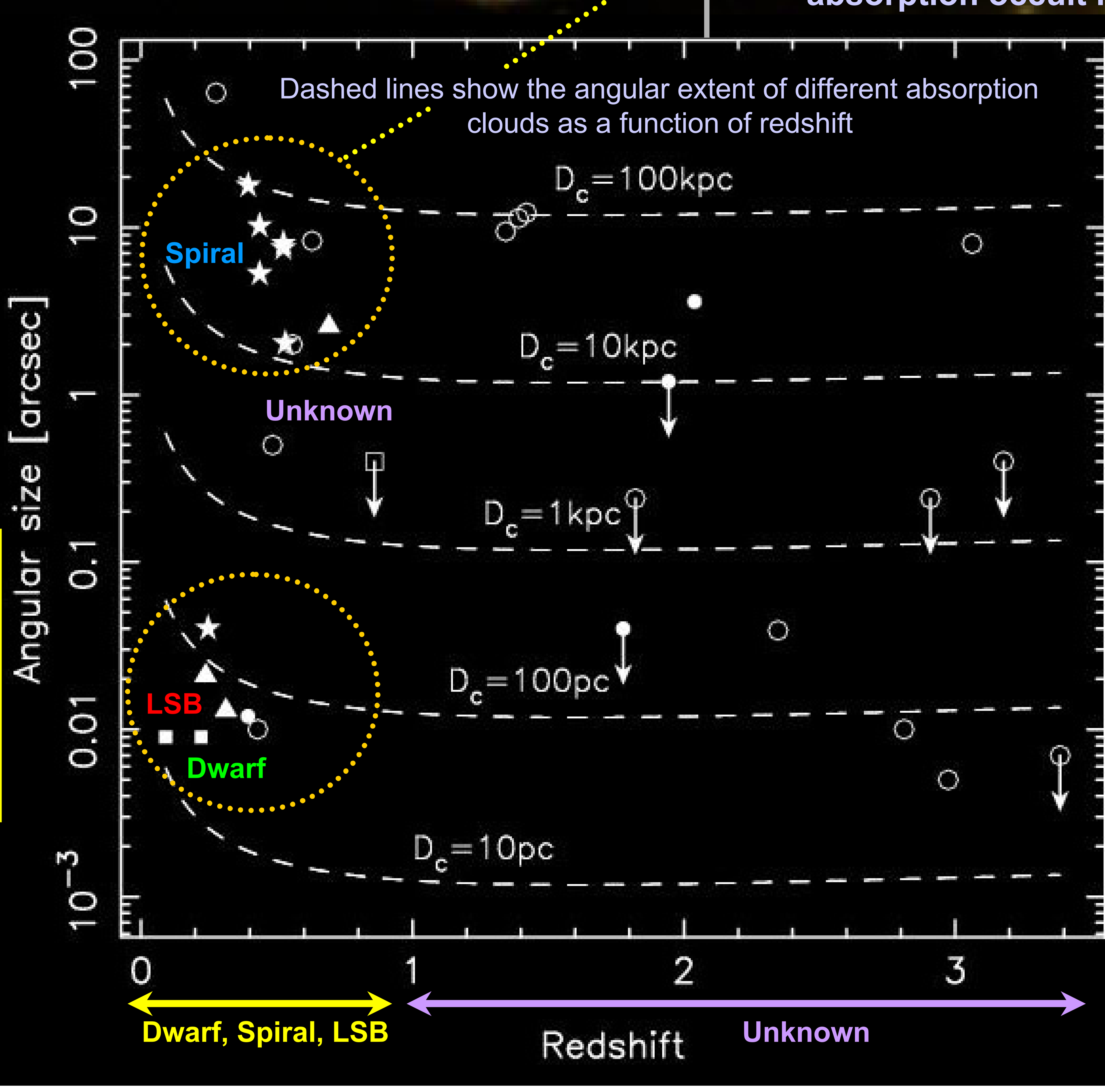
1. No DLA host galaxy identifications above z > 0.9: These are almost exclusively non-detections and occult large background continuum sources
2. At low z where hosts are identified, 21-cm absorption tends to be detected:
   a. Towards large background sources (> 1'') when DLA is associated with a large galaxy (spiral)
   b. Where the DLA occurs in LSB or dwarf galaxies, the background source is compact (< 0.1'')
3. In general, ~70% of the DLAs not detected in 21-cm absorption occult large background sources (> 1'')

Angular sizes of the background continuum sources, where the arrows represent upper limits (from VLBI & VLA observations).

Filled symbols are 21-cm detections

Unfilled are 21-cm non-detections

Key for DLA host galaxy type:
Circle – Unknown
Star – Spiral
Square – Dwarf
Triangle - LSB



CONCLUSION

In general the covering factors of DLAs occulting radio-loud quasars may be overestimated (i.e. f < 1). This would have the consequence of lowering the estimated values of the spin temperature of the gas in the galaxies responsible for the absorption. A generally lower value of f at high redshift is consistent with the hypothesis that low redshift DLAs arise from a mix of spiral, dwarfs and low surface brightness (LSB) galaxies, while the high redshift sample primarily consists of compact galaxies.

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