Molecular Hydrogen at high-z: Physical conditions in protogalaxies

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- Probing the chemical history, dust depletion and in situ-star formation

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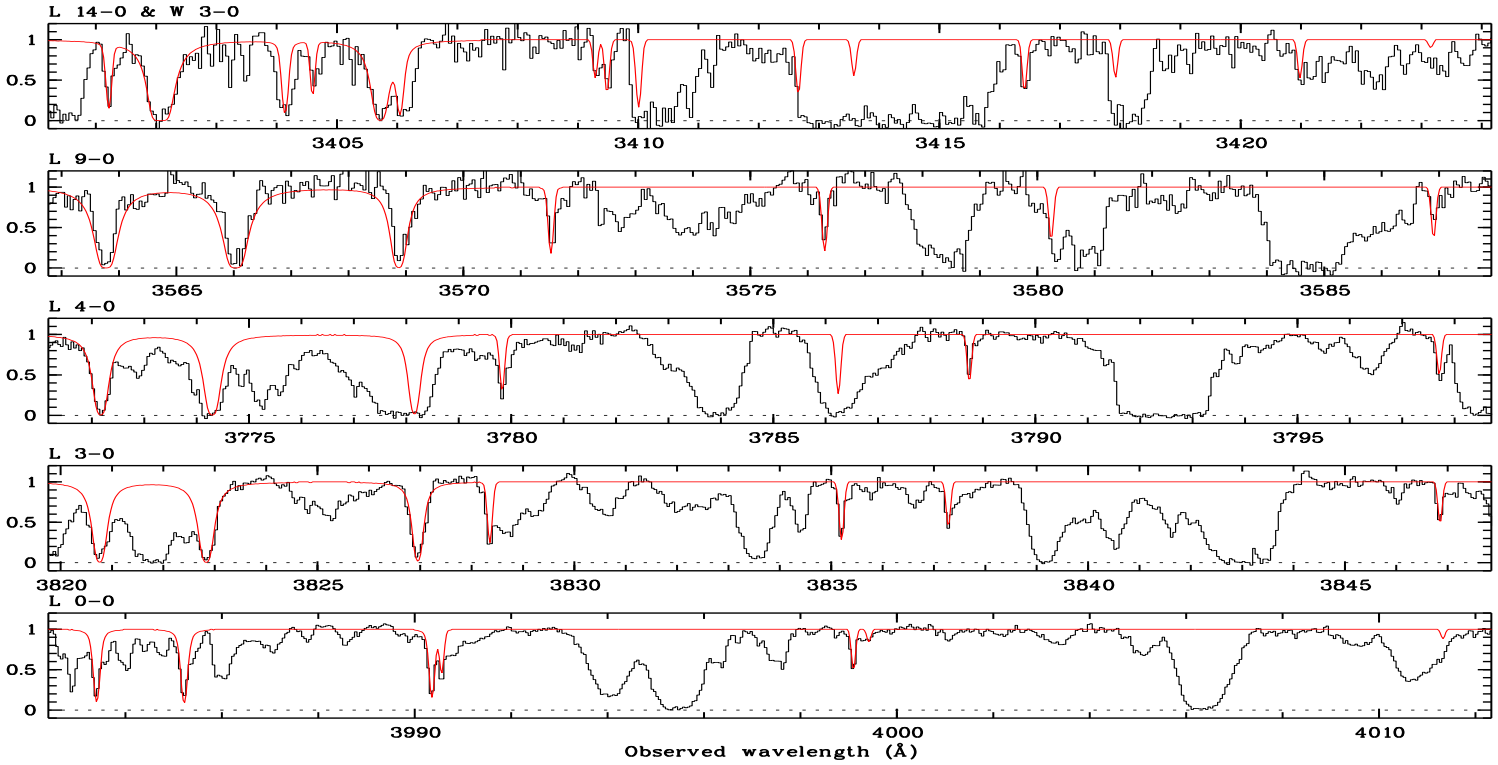
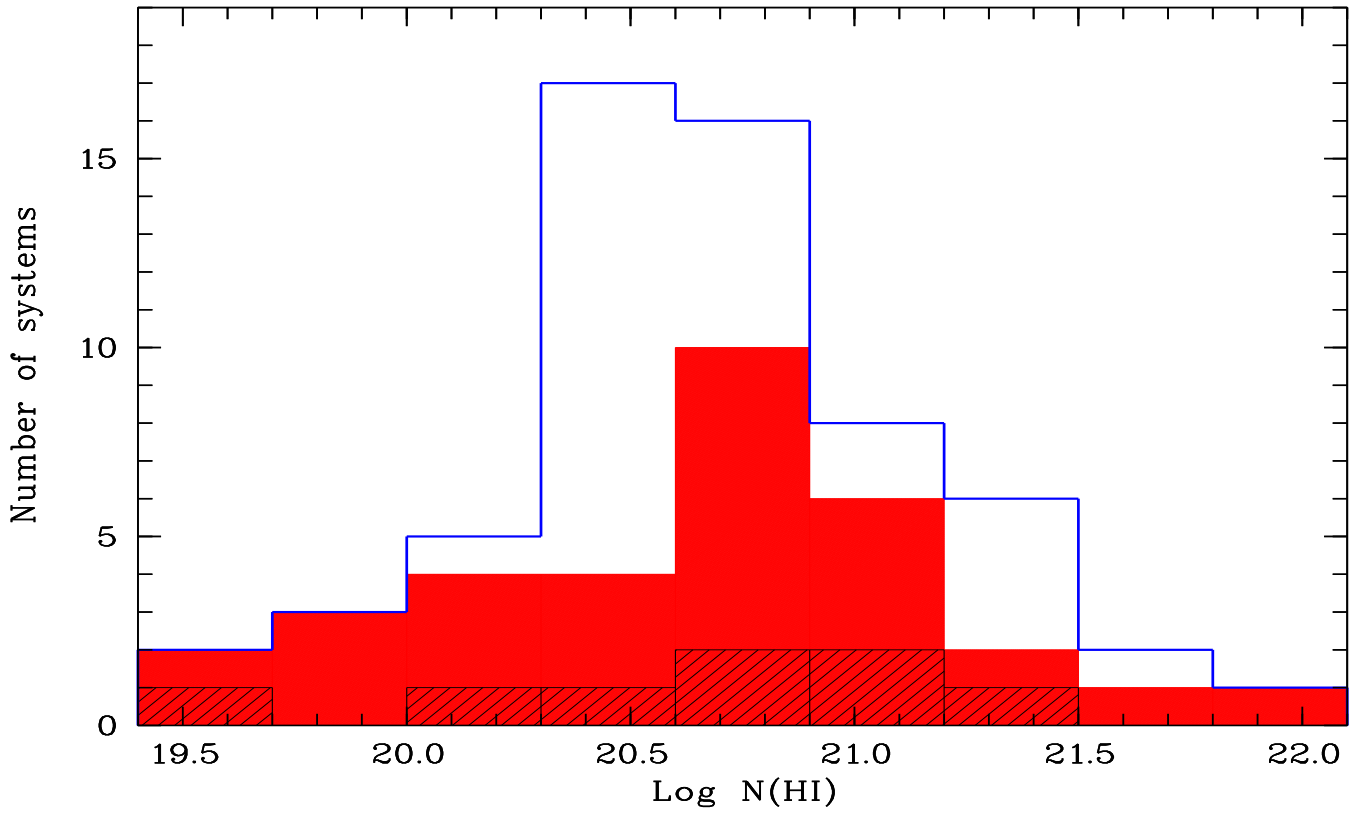
- 50% of DLAs do not show absorption due to atomic fine-structure lines or H_2.

RESULTS OF UVES SURVEY OF H_2 IN DLAs

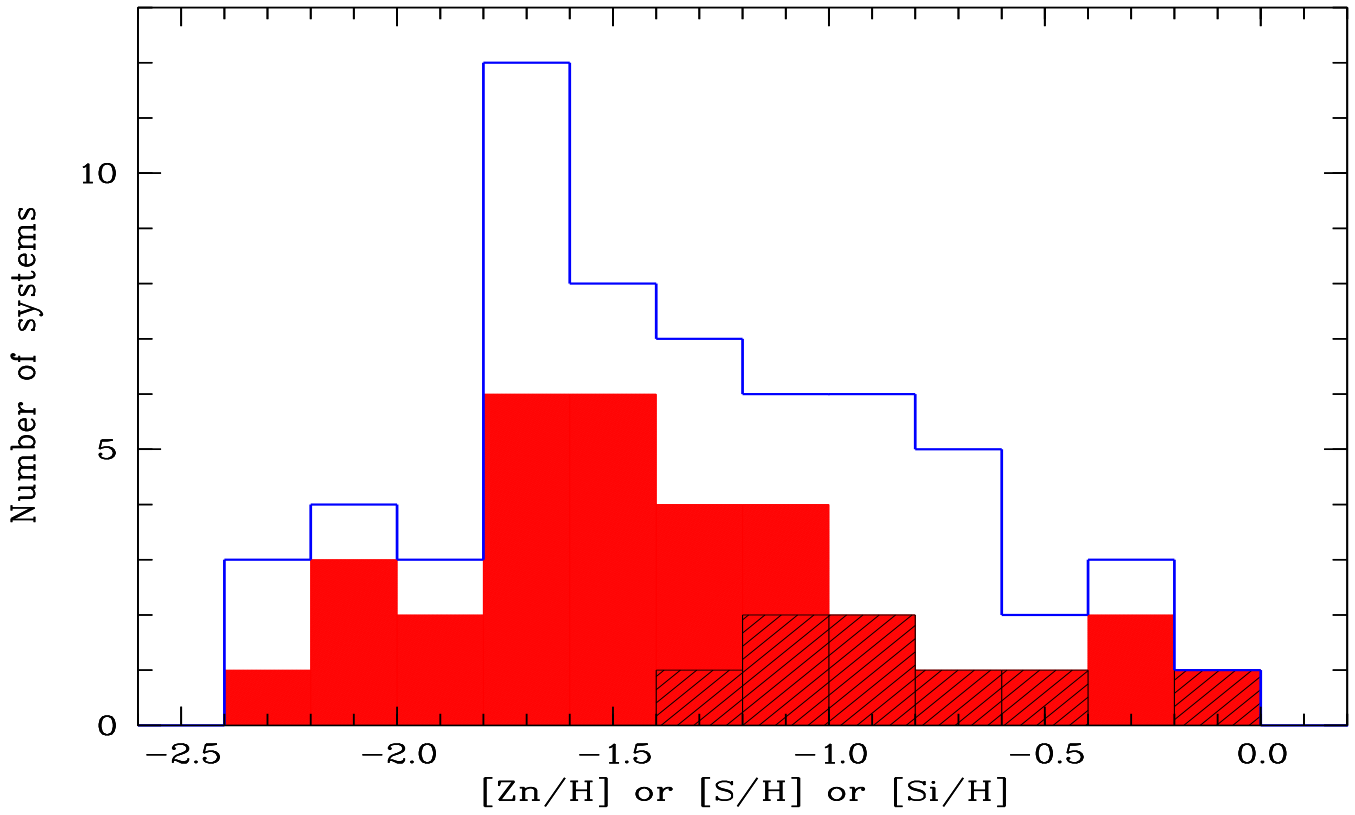
z_{abs} = 2.5947 DLA toward Q 0405−443.



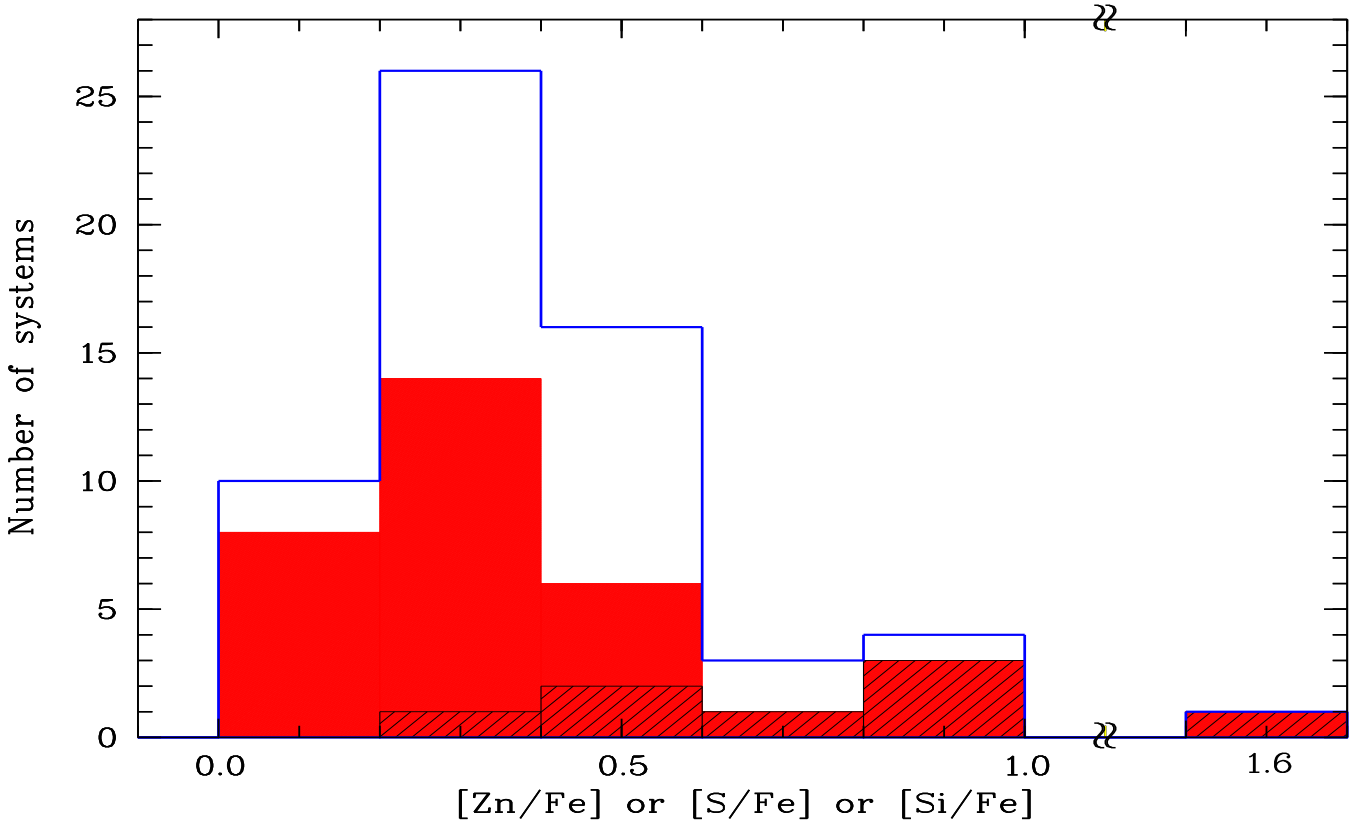
H_2 detection is independent of N(H I)



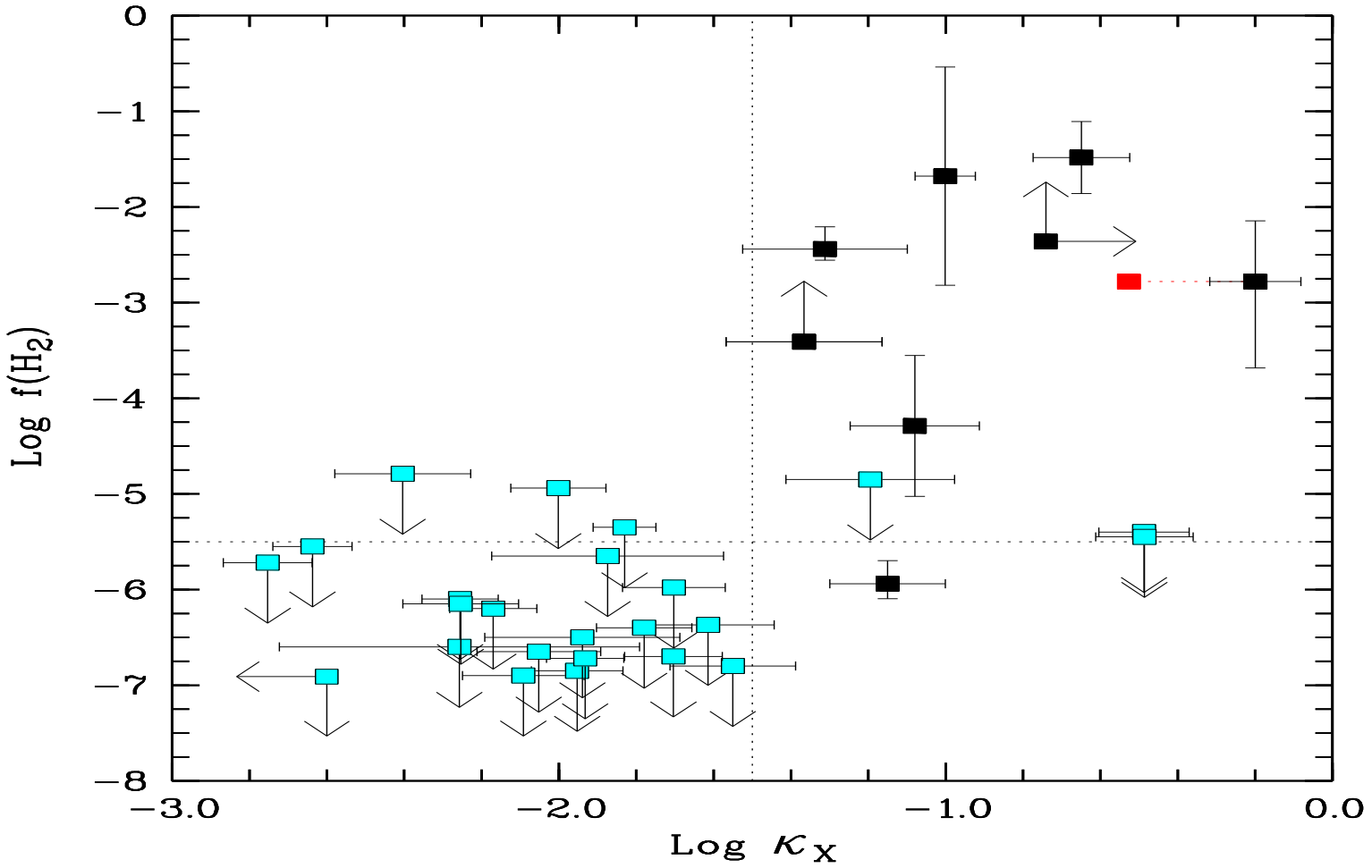
H_2 is frequently detected in high Z systems:



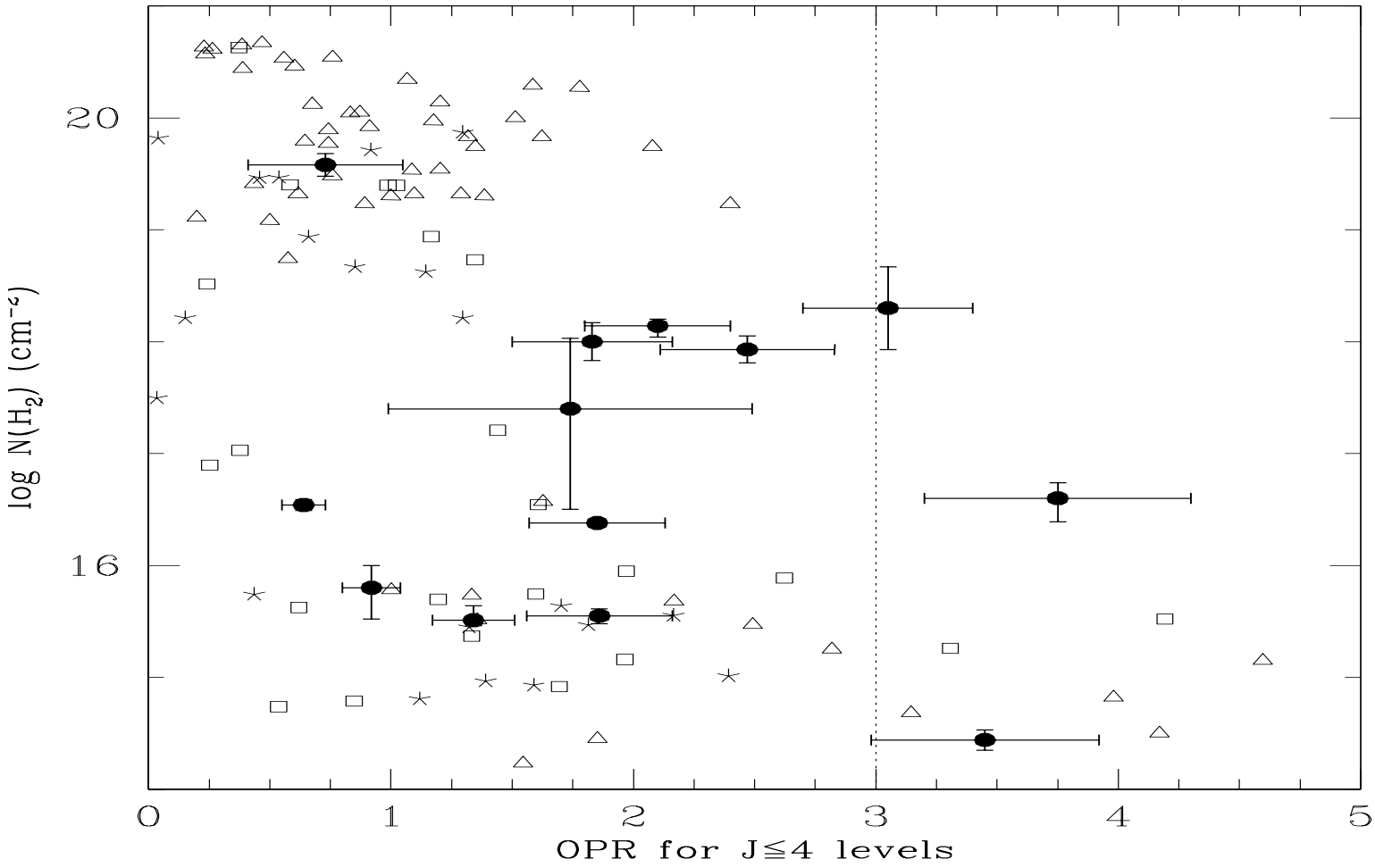
H_2 is detected in DLAs with higher depletion:



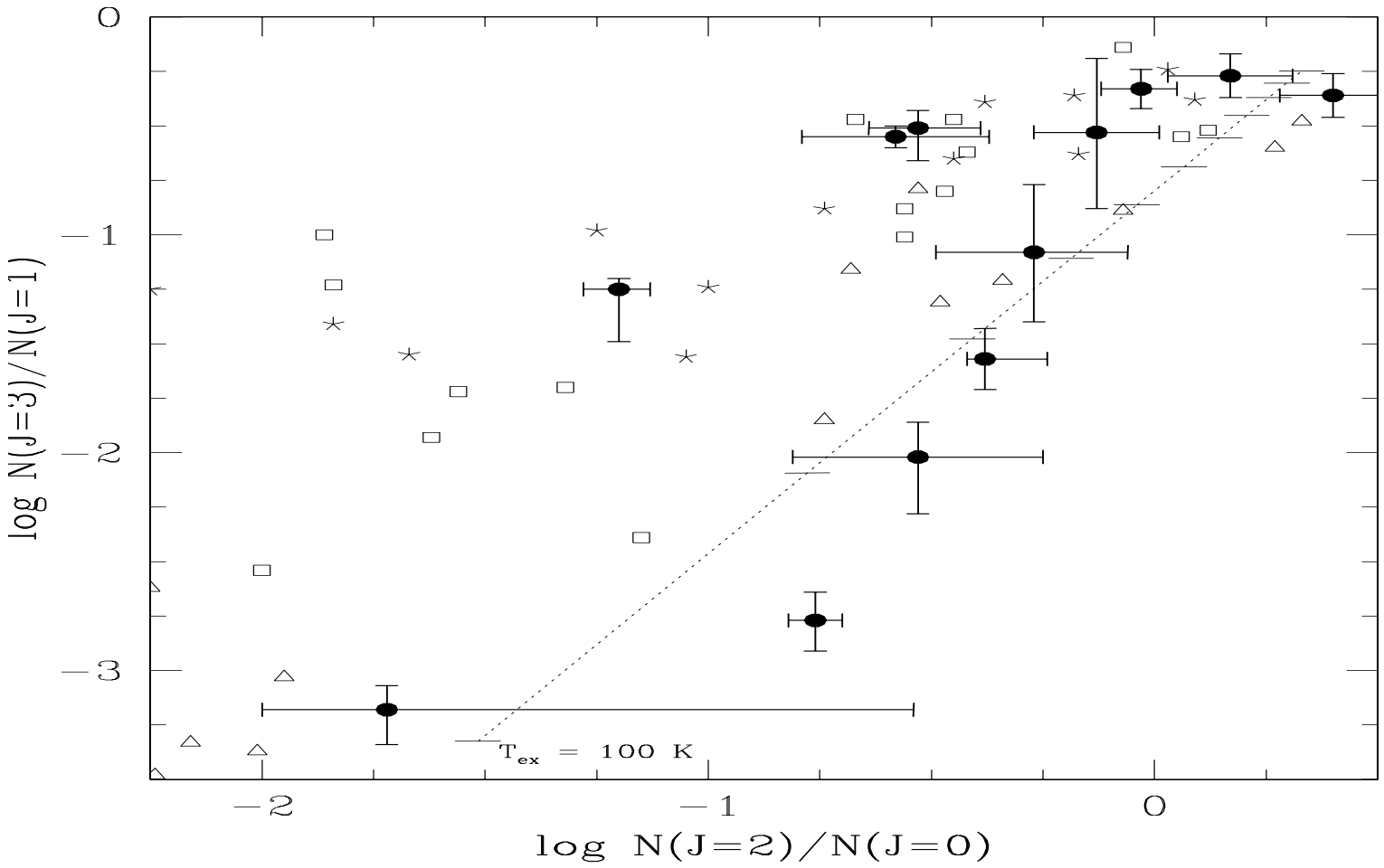
fraction of H_2 vs. dust content:



Kinetic temperature of the gas : 153±78 K



Rotational Excitation of H_2: Radiation field



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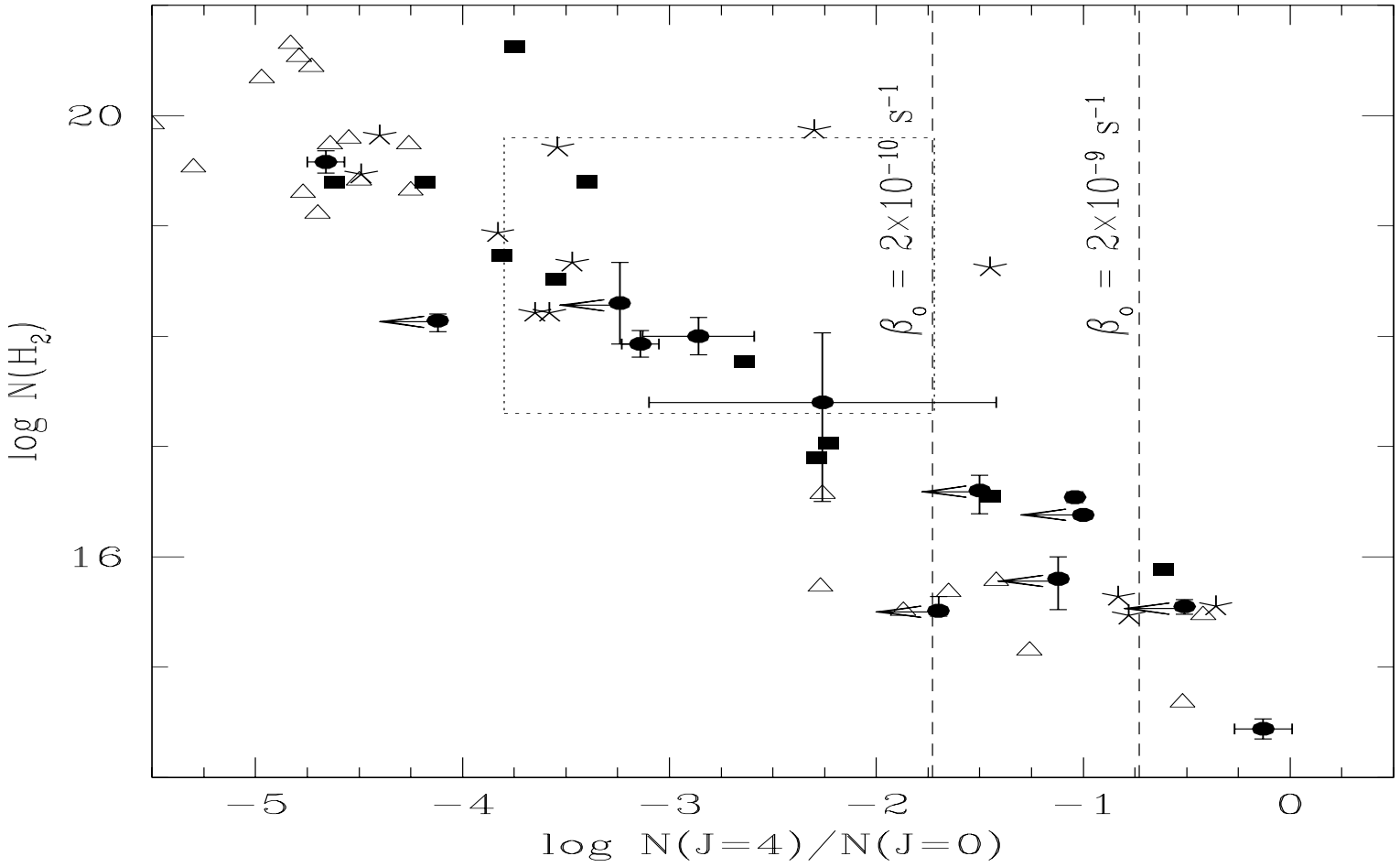
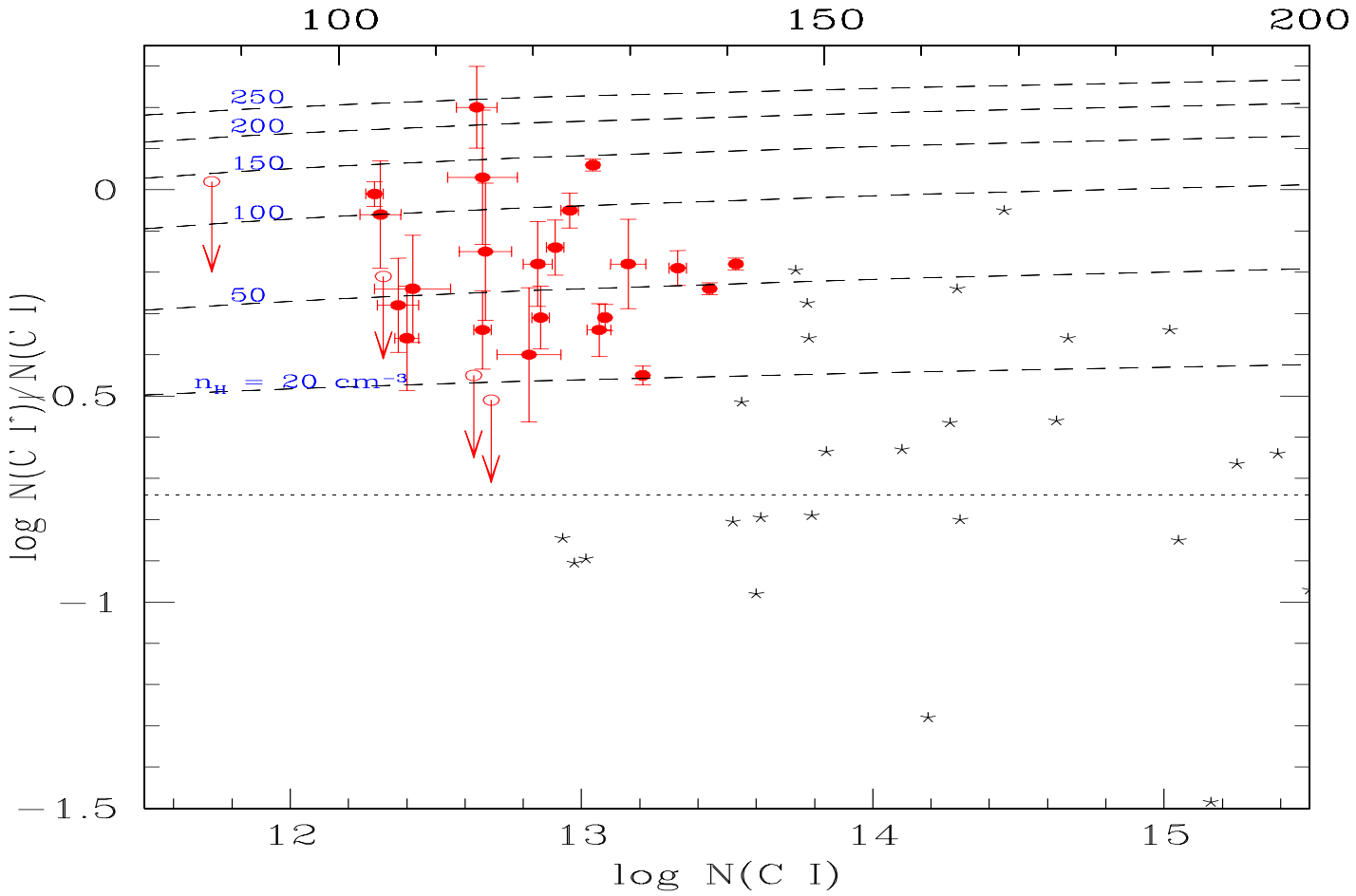
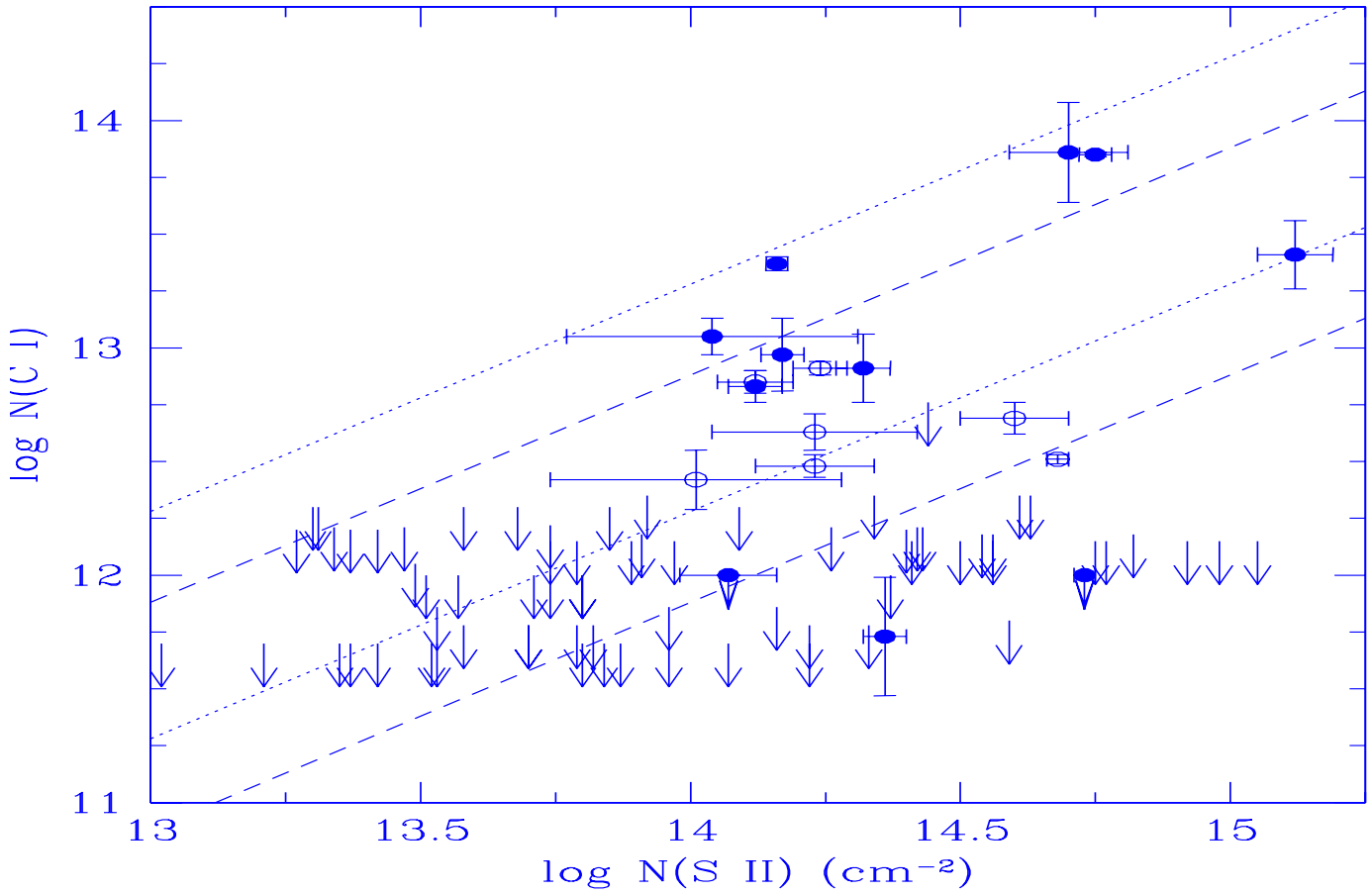


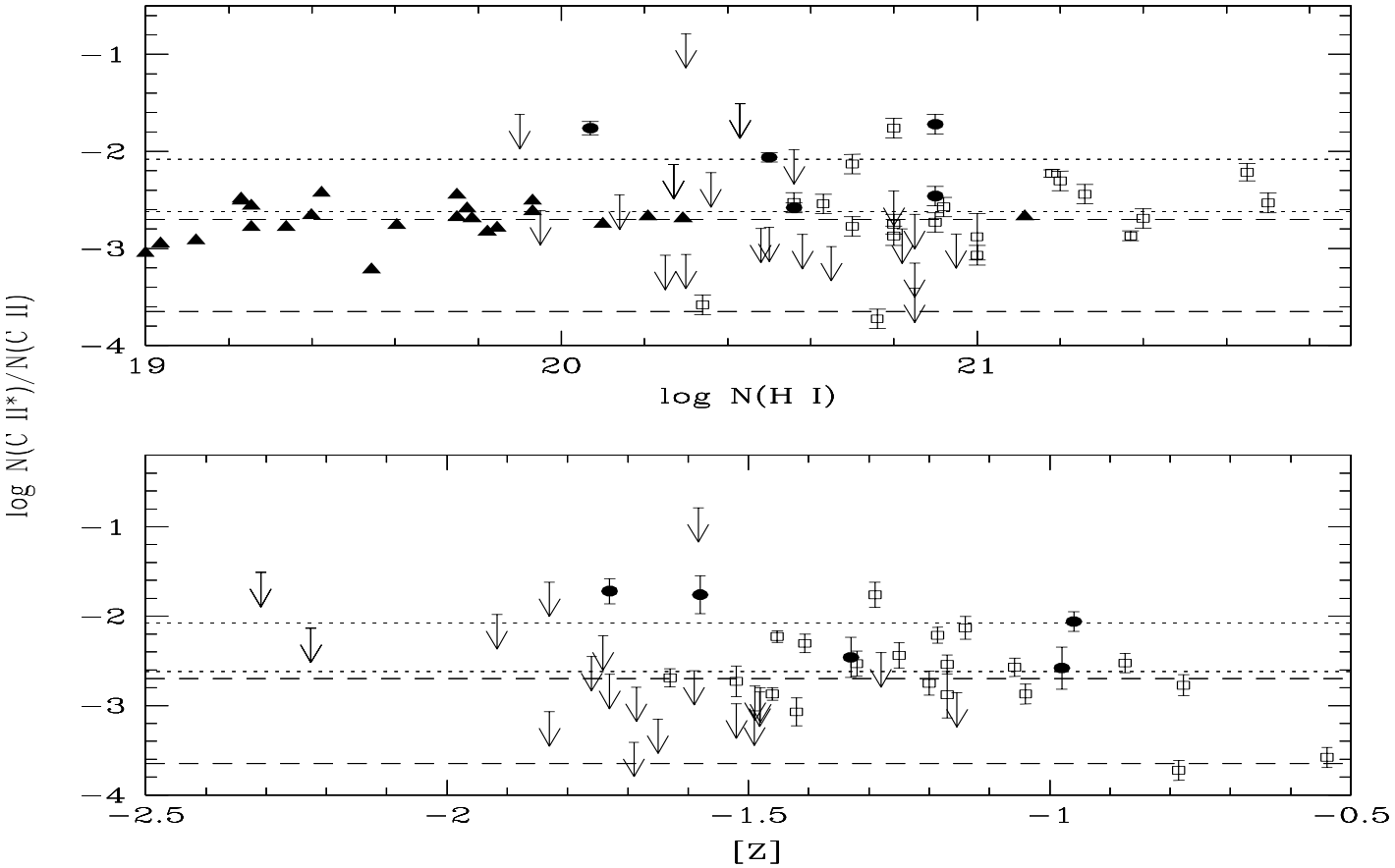
Fine-structure excitation of C I: Pressure/density



Carbon ionization:



C II* excitation:



C II* excitation:

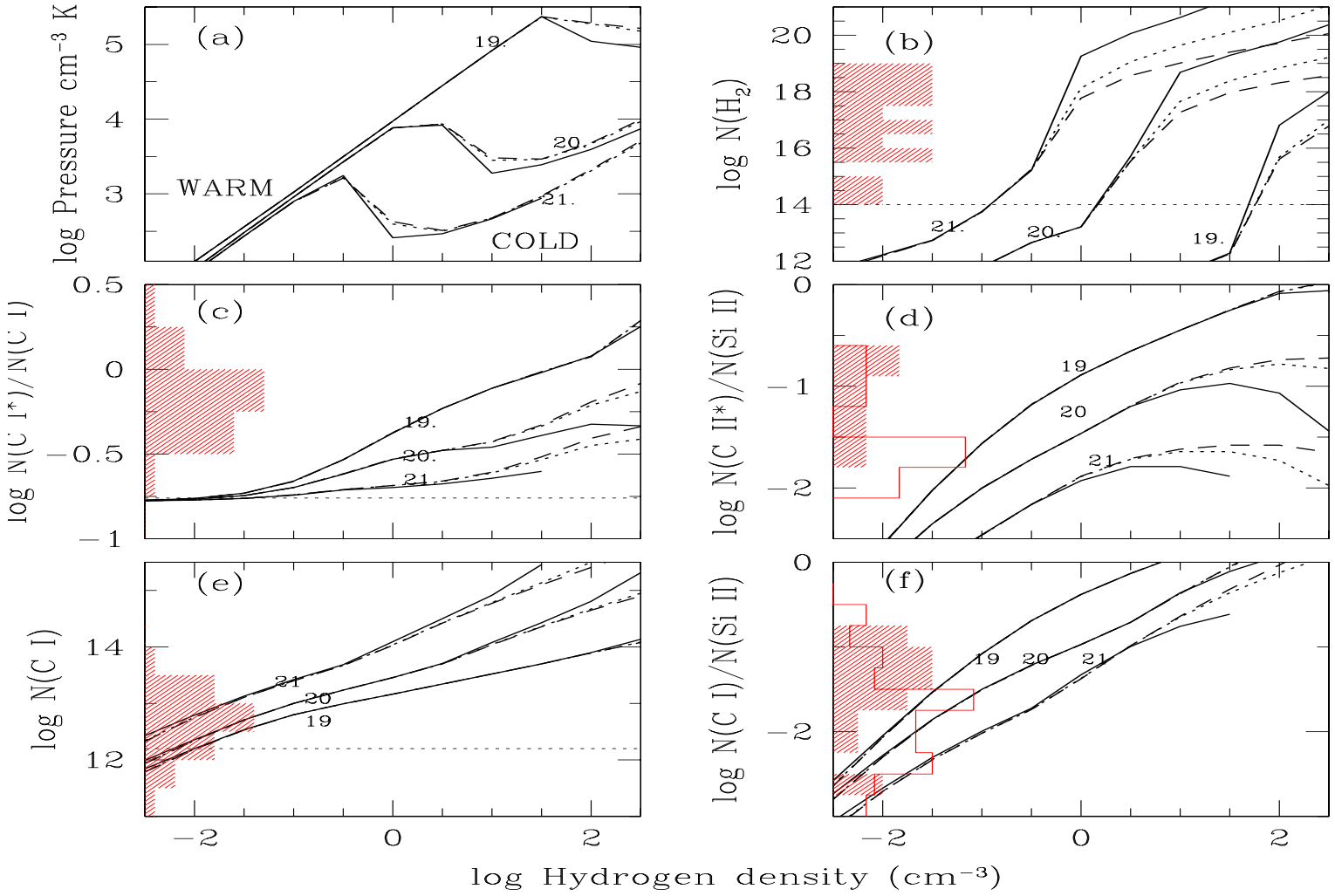
Table 1: Systems without H_2 detection

QSO	z_{abs}	log x(Al III)	n_H (cm^{-3})			
			CNM[1]	WMN[2]	Ionized[3]	Max[4]
$0058-292$	**2.671**	**....**	**3.1**	**1.2**	**0.3**	**<3**
$0112-306$	**2.423**	-1.46	**24.4**	**9.6**	**2.3**	**<15**
$0135-273$	**2.800**	-1.86	**60.0**	**23.4**	**5.6**	**<5**
$0405-445$	**2.550**	-1.58	**7.3**	**1.8**	**0.4**	**<4**
$0841+129$	**2.374**	-1.16	**11.3**	**2.8**	**0.7**	**<22**
$1157+014$	**1.943**	-1.68	**16.3**	**4.0**	**1.0**	**<3**
$1223+178$	**2.465**	-1.35	**9.4**	**2.3**	**0.6**	**<2**

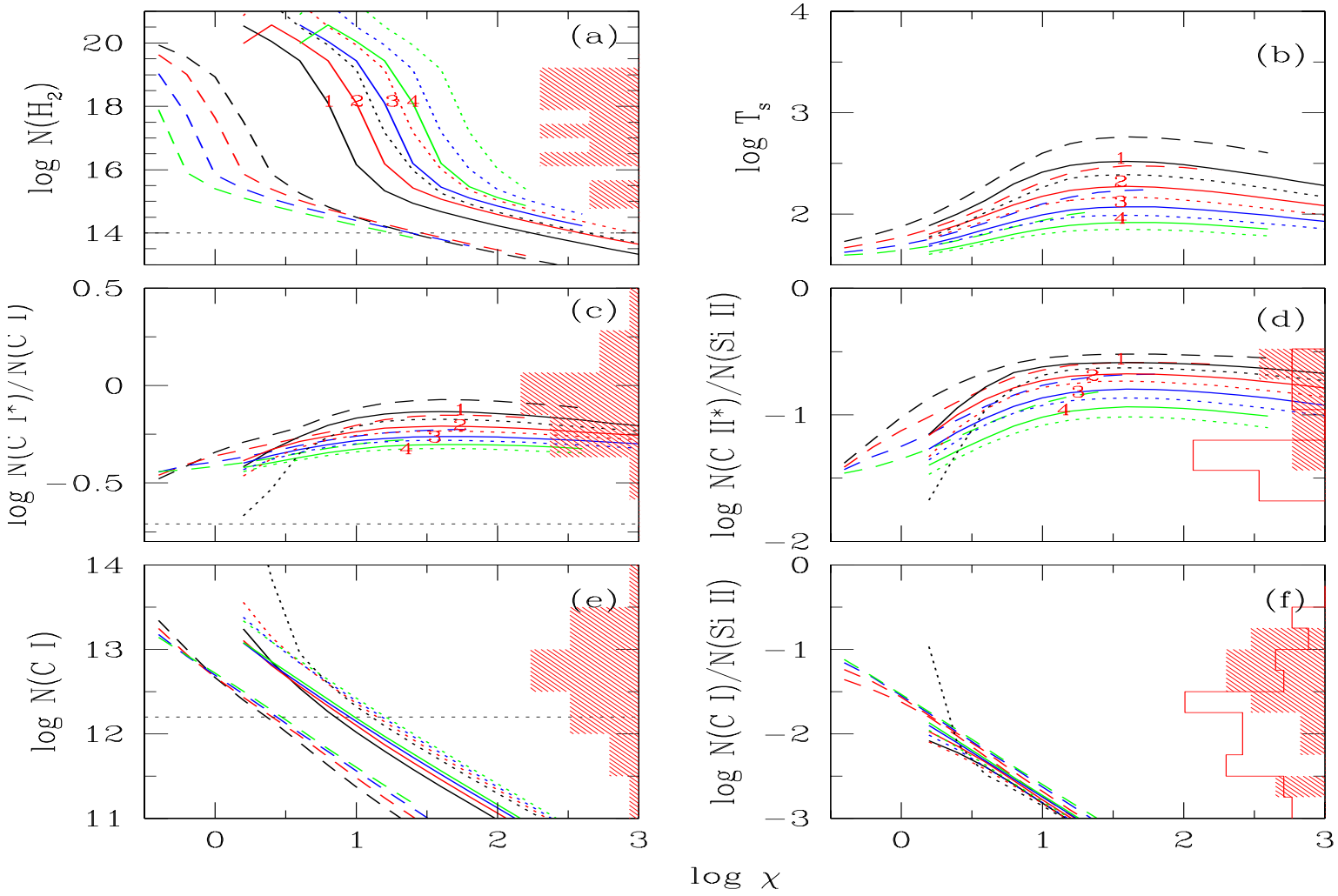
[1] T = 100 K and n_e/n_H = 0.001; [2] T = 8000 K and n_e/n_H=0.01

[3] T = 10^4 K and n_e/n_H = 0.1; [4] from H_2 equilibrium formation

PDR modeling of DLAs: HM spectrum



PDR modeling of DLAs: Stellar radiation



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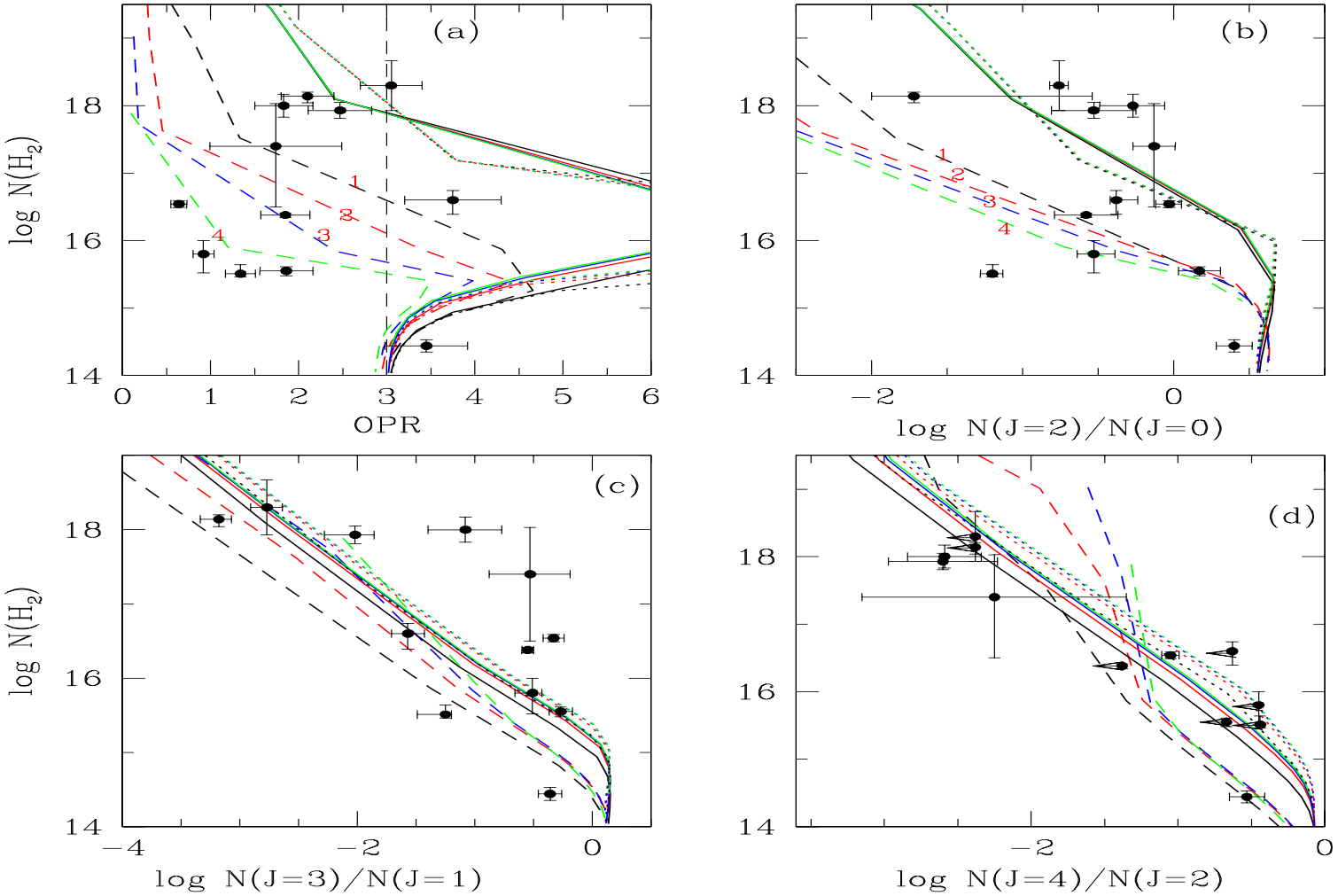

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- 20% of the DLAs show gas with 75$\leq$ T(K)$\leq$230, 20$\leq n_H \leq$100 cm^{-3} and radiation field inexcess of mean local ISM UV field.

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- If 20% of general DLA population has this SFR then DLAs will contribute half the SFR measured from LBGs.

References:

- Petitjean, Srianand, Ledoux, 2000, A&A, 364, 26
- Srianand, Petitjean, Ledoux, 2000, Nature, 408,931
- Ledoux, Srianand, Petitjean, 2002, A&A, 392, 781
- Petitjean, Srianand, Ledoux, 2002, MNRAS, 332, 383
- Ledoux, Petitjean, Srianand, 2003, MNRAS,346, 209
- Srianand et al., 2005a, MNRAS (Preprint)
- Srianand et al., 2005b, MNRAS (Preprint)