21cm - optical correlation I

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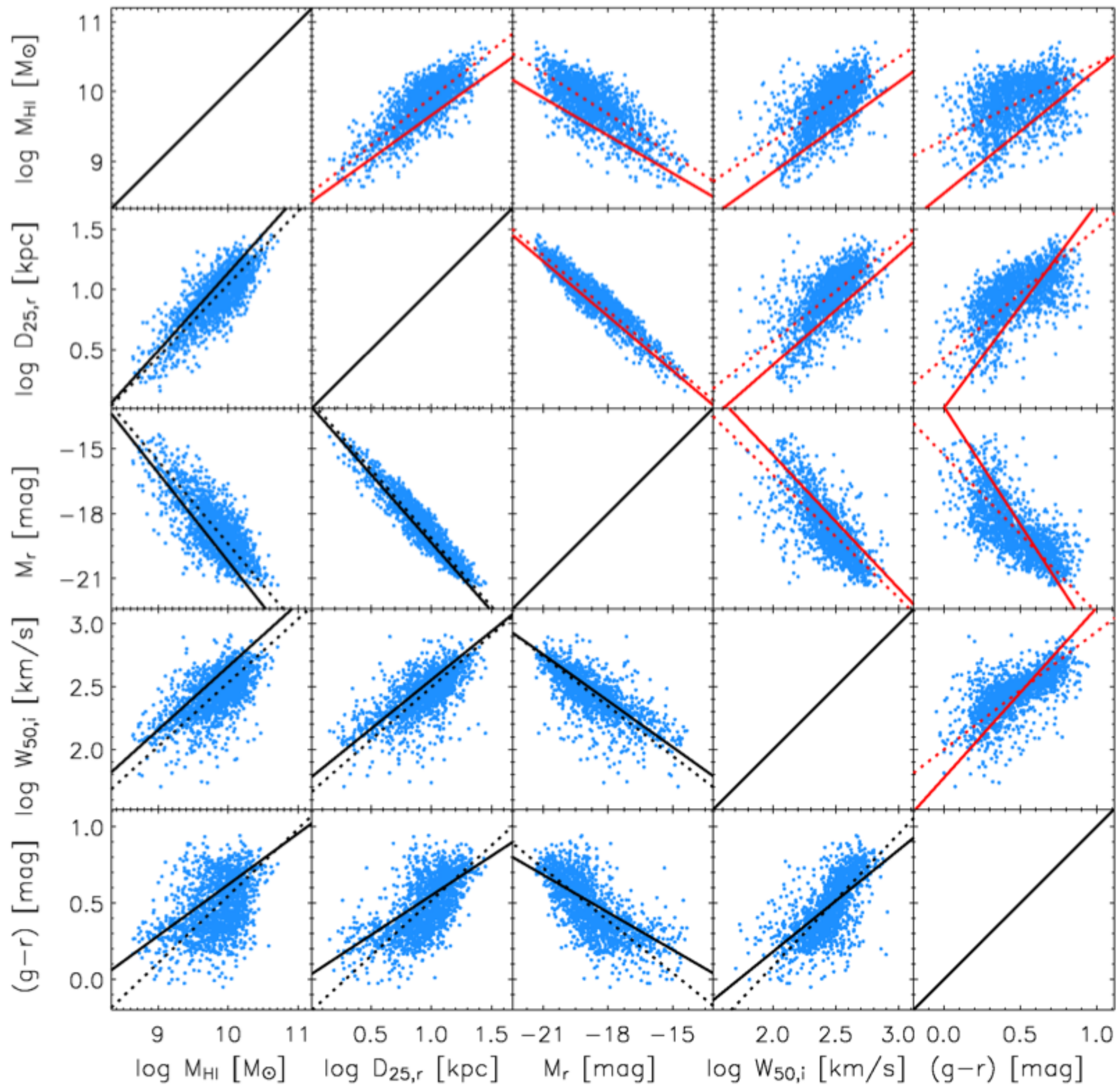
Introduction

- Goal: perform a simulated 21-cm sky map to compare to measurements
  - To estimate the 21-cm HI emission we need to (know) estimate the HI mass
  - We can do it using optical observables taken from galaxy survey catalogs

Starting point

- "HI content and optical properties of field galaxies from the ALFALFA survey. II multivariate analysis of a galaxy sample in *low density environments*", Toribio etal. 2011. arXiv:1103.0990.
- Uses the Arecibo Legacy Fast ALFA (ALFALFA) blind extragalactic survey data and finds the optical counterparts in SDSS catalog (DR7 release).
- Selects a LDE-High Quality sample of 1624 nearby objects ($z \leq 0.6$).
- A correlation is made between $\log(M_{HI}/M_{\odot})$ and:
  - $Log_{10}(D_{25})$: isophotal major-axis diameter in r-band (6165 Å)
  - M_r: absolute Petrosian magnitude in r-band
  - (g-r): color from model magnitudes (g-band: 4686 Å)
  - $Log_{10}(W_{50})$: 21-cm linewidth at 50%-peak level



Red: direct regression fits; Black: orthogonal fits; Solid: $1/V_{max}$ weight; Dotted: unweighted.

Table 3. Coefficients of $M_{\mathrm{H\,I}}$ Predictions from Single and Multiple Linear Regression Models

Weighting	X_1	X_2	a_0			a_1			a_2			Residual
$1/V'_{\mathrm{max}}$	$\log D_{25,r}$		8.72	±0.06	±0.06	1.25	±0.06	±0.07				0.23
	M_r		6.44	±0.20	±0.21	−0.18	±0.01	±0.01				0.25
	$\log W_{50}$		6.54	±0.27	±0.20	1.30	±0.11	±0.09				0.28
	$(g-r)$		8.84	±0.11	±0.12	1.81	±0.29	±0.40				0.33
	$\log D_{25,r}$	M_r	7.26	±0.12	±0.04	0.66	±0.03	±0.01	−0.10	±0.006	±0.002	0.22
None	$\log D_{25,r}$		8.85	±0.04	±0.03	1.37	±0.04	±0.03				0.21
	M_r		6.44	±0.09	±0.08	−0.20	±0.004	±0.002				0.23
	$\log W_{50}$		7.17	±0.14	±0.16	1.21	±0.05	±0.06				0.28
	$(g-r)$		9.61	±0.04	±0.04	1.10	±0.08	±0.07				0.32
	$\log D_{25,r}$	M_r	6.89	±0.05	±0.02	0.61	±0.01	±0.005	−0.10	±0.002	±0.001	0.23

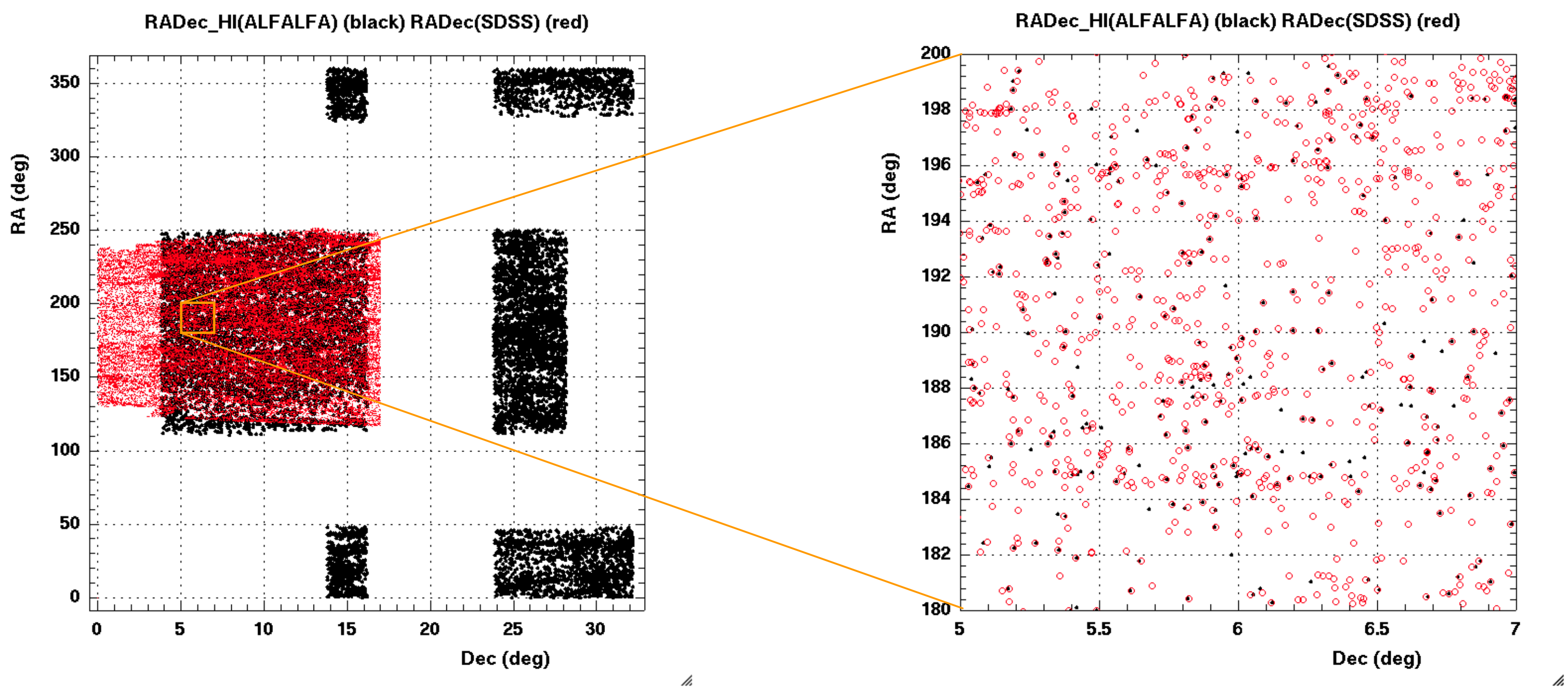
Table 4. Coefficients of Orthogonal Fits between Pairs of Variables

Weighting	Y	X: $\log D_{25,r}$		M_r		$\log W_{50}$		$(g-r)$	
		a_0	a_1	a_0	a_1	a_0	a_1	a_0	a_1
$1/V'_{\mathrm{max}}$	$\log M_{\mathrm{H\,I}}$	8.55±0.05	1.55±0.06	5.36±0.19	−0.24±0.010	5.01±0.30	1.99±0.13	8.45±0.12	2.99±0.29
	$\log D_{25,r}$			−2.05±0.09	−0.16±0.004	−2.28±0.21	1.29±0.14	−0.06±0.06	1.93±0.15
	M_r					1.46±1.14	−8.15±0.48	−12.8±0.40	−12.2±0.98
	$\log W_{50}$							1.73±0.06	1.50±0.13
None	$\log M_{\mathrm{H\,I}}$	8.58±0.03	1.66±0.03	5.24±0.08	−0.26±0.004	5.30±0.11	1.98±0.04	9.06±0.04	2.28±0.07
	$\log D_{25,r}$			−2.02±0.03	−0.16±0.002	−1.98±0.08	1.19±0.03	0.29±0.02	1.38±0.03
	M_r					−0.24±0.42	−7.57±0.16	−14.6±0.13	−8.74±0.26
	$\log W_{50}$							1.90±0.01	1.15±0.04

Table 5. Central Slopes of Scaling Laws between Fundamental Galaxian Properties Reported by Different Authors

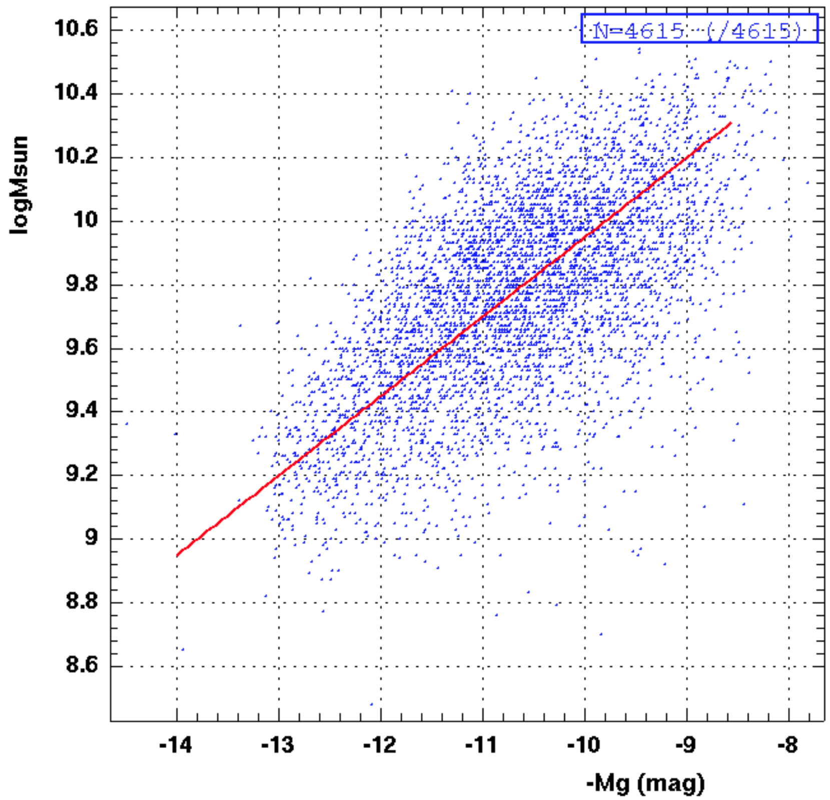
Reference	Scaling law: $M_{\mathrm{H\,I}} \sim R^{\alpha}$	$M_{\mathrm{H\,I}} \sim L^{\beta}$	$L \sim V^{\gamma}$	$R \sim L^{\delta}$	$R \sim V^{\epsilon}$
HG84 (1984)	1.8	0.66	2.6	...	...
Salpeter & Hoffman (1996)	2.0	0.74	3.7	0.37	1.4
Courteau et al. (2007)	...	...	3.4	0.32	1.1
This work	1.6	0.60	3.3	0.40	1.3

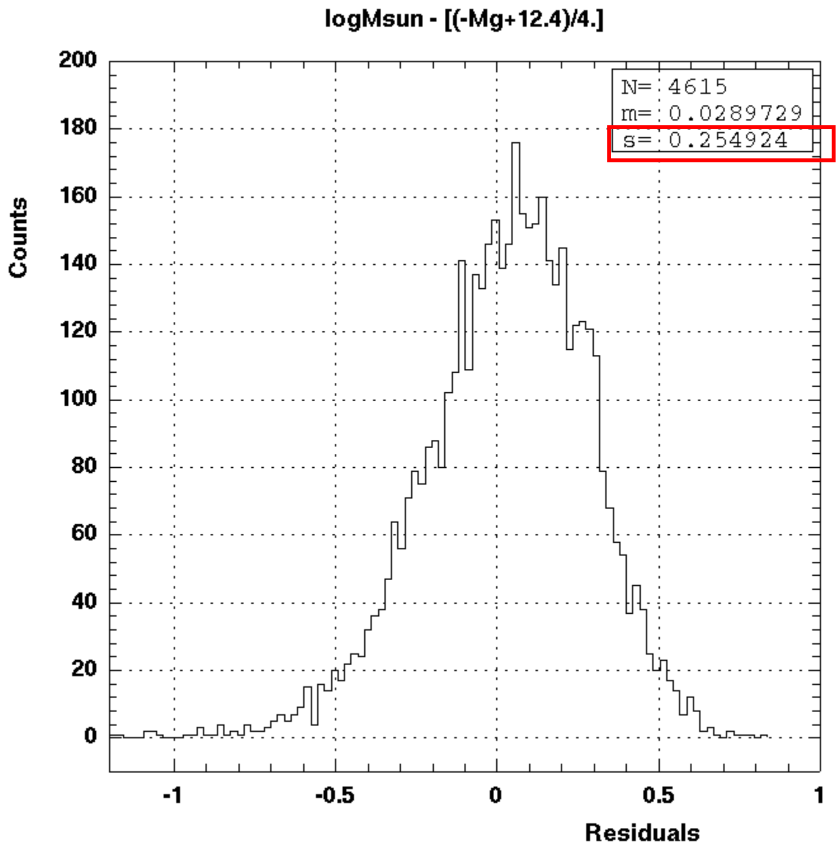
This work



- Take ~6200 paired ALFALFA-SDSS galaxies (by Toribio2011)
- Try the correlations $\log(M_{HI}/M_{\odot})$ and: M_g, (r-g) and $\log_{10}(D_{25})$
- We correct magnitudes from Galactic extinction but not for inclination (it will not be available for higher-z objects)

log($M_{HI}/M_{\odot}$) vs. M_g

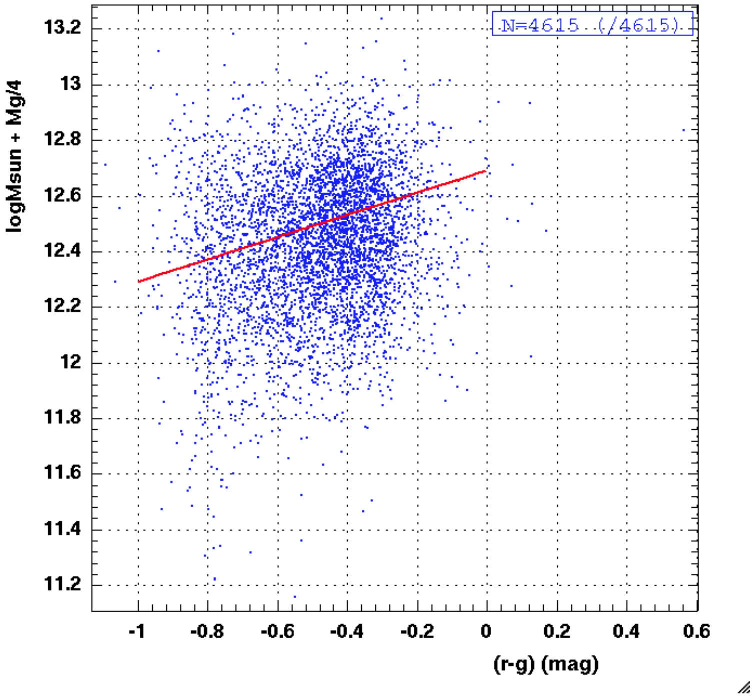


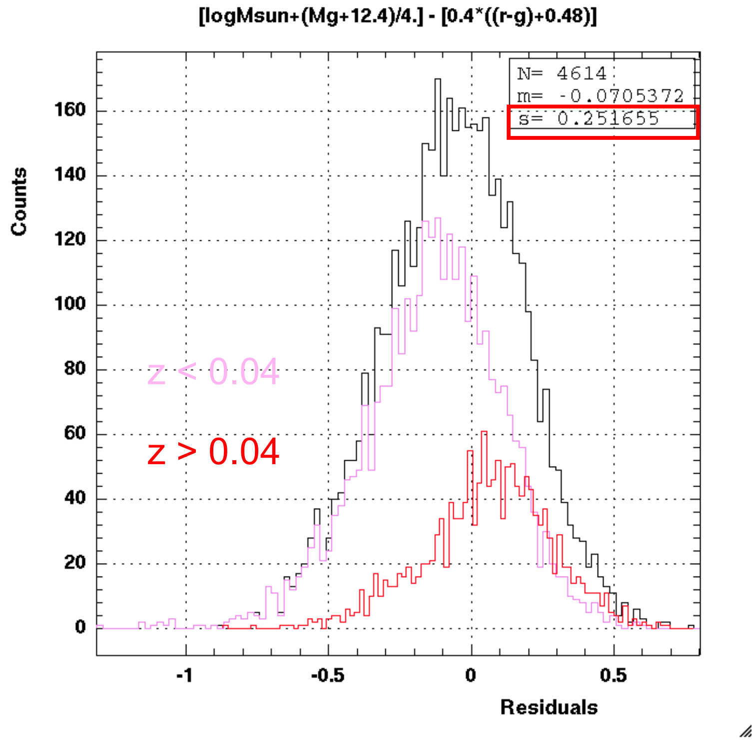


- We obtain a correlation "by eye": $logMsun = 9.35 + \frac{(-M_g + 12.4)}{4}$
- log(M_{HI}) $\propto$ M_g/4 ~ 2.5/4 log(L) $\Rightarrow$ $M_{HI} \propto L^{0.625}$

  (Toribio: $M_{HI} \propto L^{0.6}$)

$\log(M_{HI}/M_\odot) + M_g$ vs. (r-g)



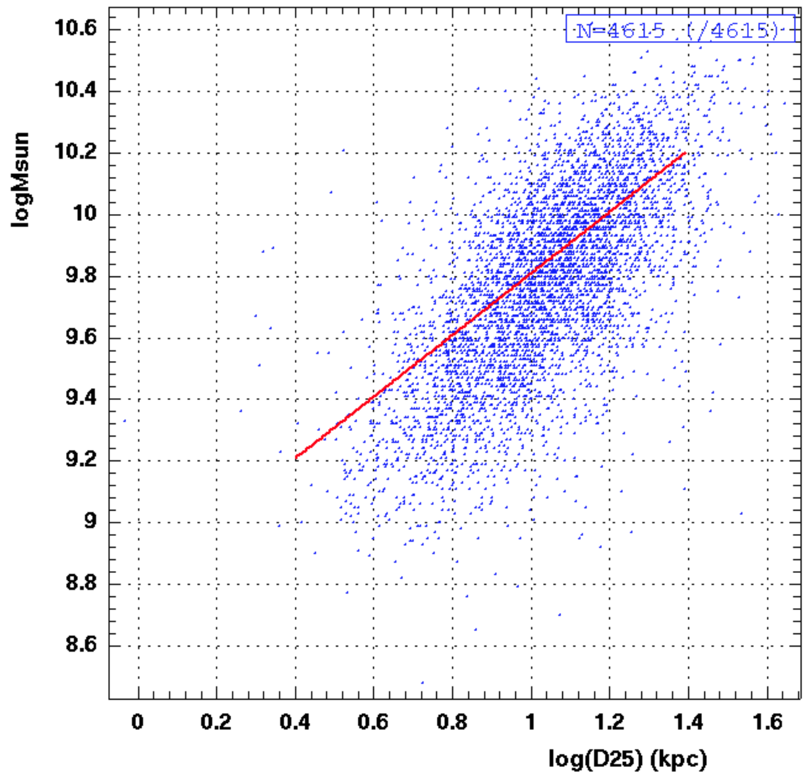


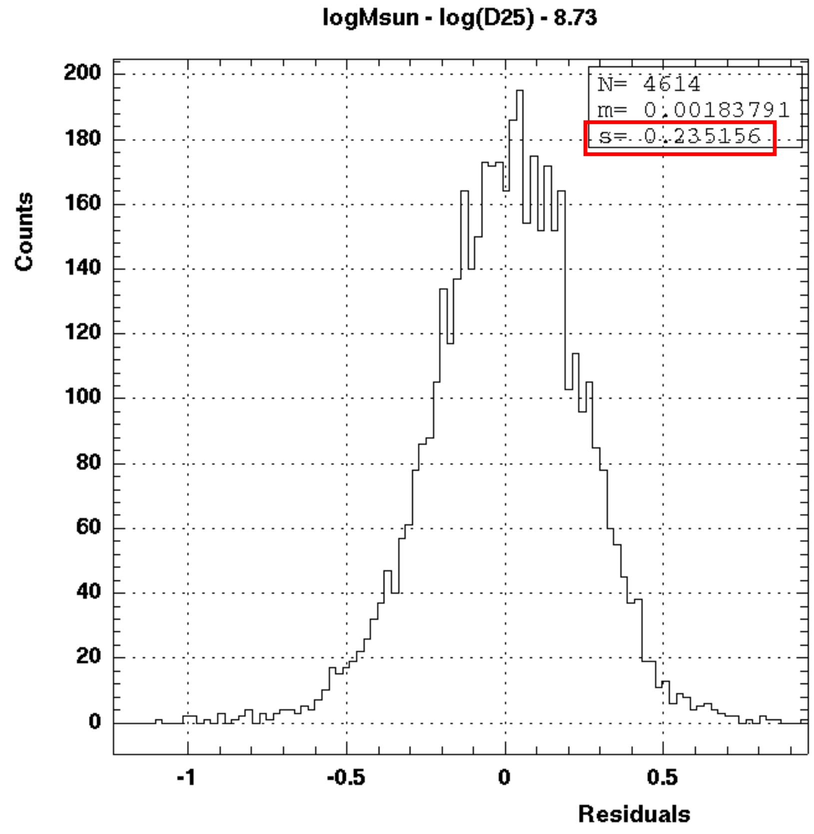
- Mass-luminosity scaling with color:

$$\log(M_{HI}/L^{0.25}) \sim 0.4\times 2.5\times\log(L_r/L_g) \Rightarrow M_{HI}/L^{0.25} \sim L_r/L_g$$

- Distance for closer objects is misestimated due to peculiar velocities ⇒ affects differently M_{HI} and $M_g/4$ ⇒ spread of residuals distribution
  - $M_{HI} \propto Dist^2 \times F_{HI} \Rightarrow \log(M_{HI}) \sim 2\times\log(Dist)$
  - $M_g/4 \sim 5/4\times\log(Dist)$

$\log(M_{HI}/M_{\odot})$ vs. $\log(D_{25})$





- Best correlation, but not too far from the others
- The measurement of D_{25} for distant objects might not be precise/available

Conclusions

- We find correlations between $\log(M_{HI}/M_{\odot})$ and some optical observables
  - $\log(M_{HI}/M_{\odot})$ vs. Mg, $\sigma_{res} \sim 0.255$
  - $\log(M_{HI}/M_{\odot})+M_g$ vs. (g-r), $\sigma_{res} \sim 0.252$
  - $\log(M_{HI}/M_{\odot})$ vs. D_{25}, $\sigma_{res} \sim 0.235$
  - and find a scaling $M_{HI} \propto L^{0.62}$

  which are not far from Toribio2011 results
- For more precise coefficients $\Rightarrow$ determination of the correlation matrix
- We can make a first estimation of 21-cm sky map