THE GEOMETRY OF COLD, METAL-ENRICHED GAS AROUND GALAXIES AT $Z \sim 1.2$

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ABSTRACT

We present the first results from a Hubble Space Telescope WFC3/IR program, which obtained direct imaging and grism observations of galaxies near quasar sightlines with a high frequency of uncorrelated foreground Mg II absorption. These highly efficient observations targeted 54 Mg II absorbers along the line of sight to nine quasars at $z_{qso} \sim 2$. We find that 89% of the absorbers in the range $0.64 < z < 1.6$ can be spectroscopically matched to at least one galaxy with an impact parameter less than 200 kpc and $|\Delta z|/(1+z) < 0.006$. We have estimated the star formation rates and measured structural parameters for all detected galaxies with impact parameters in the range 7-200 kpc and star formation rates greater than 1.3 $M_\odot$ yr^{-1}. We find that galaxies associated with Mg II absorption have significantly higher mean star formation rates and marginally higher mean star formation rate surface densities compared to galaxies with no detected Mg II. Nearly half of the Mg II absorbers match to more than one galaxy, and the mean equivalent width of the Mg II absorption is found to be greater for groups, compared to isolated galaxies. Additionally, we observe a significant redshift evolution in the physical extent of Mg II-absorbing gas around galaxies and evidence of an enhancement of Mg II within 50° of the minor axis, characteristic of outflows, which persists to 80 kpc around the galaxies, in agreement with recent predictions from simulations.

Subject headings: galaxy evolution: general; quasar absorption lines: general

1. INTRODUCTION

The in-situ evolution of galaxies is understood to be regulated by the accretion, consumption, heating, and expulsion of gas. Distant luminous quasars are uniquely powerful probes of these gaseous processes, as they enable the detection of intervening galaxies by virtue of their gas cross-sections, irrespective of their stellar lumi-

galaxies (e.g., Bahcall & Spitzer 1969; Prochaska & Wolfe 1997), large-scale star-formation driven outflows (e.g., Nulsen et al. 1998), and gas being stripped or accreted within the extended halos of galaxies (e.g., Kacprzak et al. 2010; Stewart et al. 2011).

Despite the potential utility of Mg II for tracing this wide variety of physical processes that have been impli-

The most prolific metal absorption transition in optical quasar spectra, singly-ionized magnesium (Mg II), traces T $\sim 10^4$ K photo-ionized gas in a wide range of environments in and around intervening galaxies.

In the past decade, the expansive spectroscopic quasar sample of the Sloan Digital Sky Survey (SDSS) has facilitated
the detection of tens of thousands of Mg II absorbers.

Studies of directly detected host galaxies at $z < 0.5$ indicate that the origins of Mg II are not clear in the case of the more common population of faint absorbers with W < 1A, suggesting that Mg II most frequently probes infalling gas from the halos of normal galaxies.

Some absorbers can be explained by the dynamics of gas in an intragroup medium (Gauthier 2013**). Связь с отдельными галактиками часто не очевидна.**

Данные наблюдений

WFC3/IR camera (0.06’’/pix) and grism (46A/px) aboard the HST to measure the star formation rates (SFRs), impact parameters, inclination angles and structural parameters for Mg II-selected galaxies (Z>0.64) .

Прямое изображение + 2 ориентации гризмы на каждый квазар

Рассмотрено 9 квазаров (изображения+ информация о спектрах объектов). 8 пригоды для анализа спектров галактикю

Абс.линии Mg ii в каждом спектре QSO имеют несколько z, всего – 54 системы с различными Z.

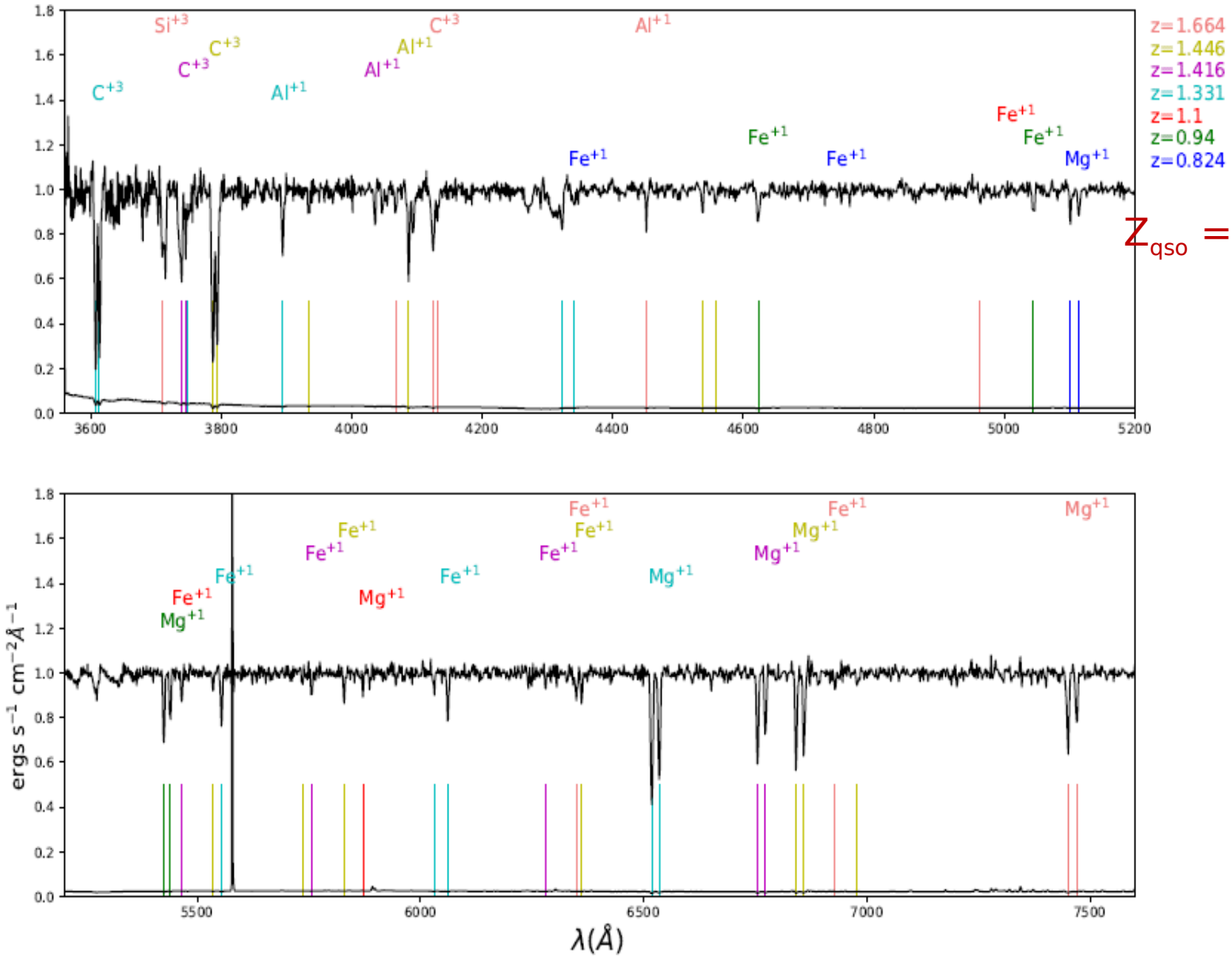


FIG. 1.— An annotated portion of the continuum-normalized SDSS BOSS spectrum of SDSS J083852.05+025703.7, one of the nine quasars targeted in this work. The uncertainty in the normalized flux per pixel is shown near the bottom of each panel

В пределах 20’’ от квазаров измерены Z (по Ha) и W_{Ha} для почти ста галактик с 0.64<Z<1.6

nt of the nine flelds targeted in this survey
e determined to be viable for the analysis
absorber-galaxy
relations.

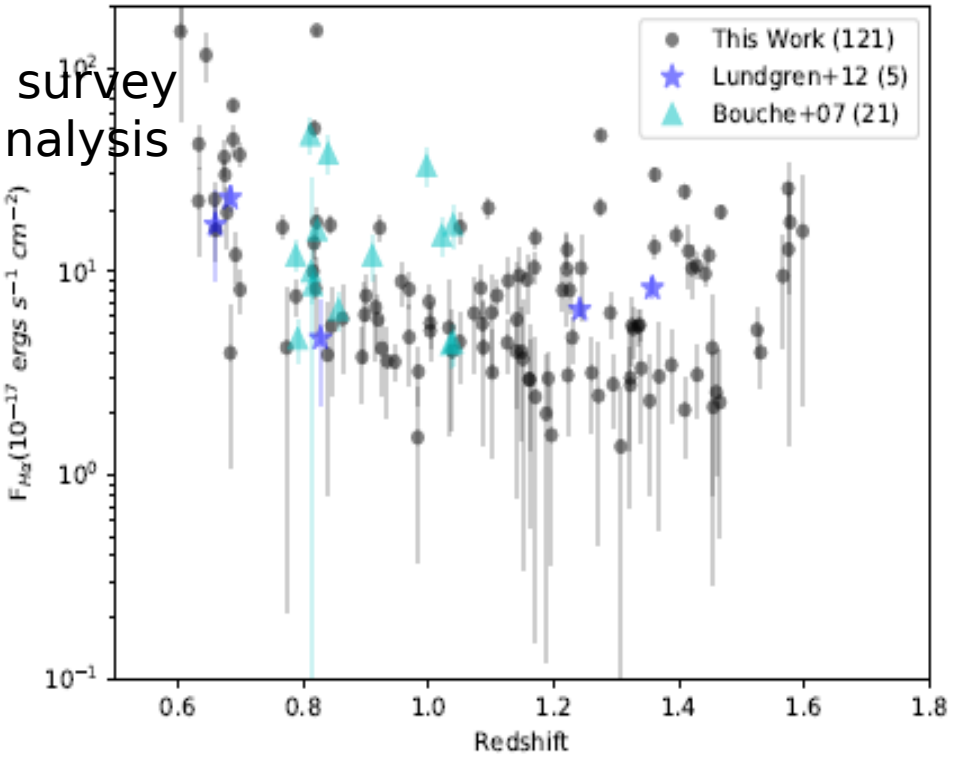


FIG. 3.— Hα flux versus redshift for all the galaxies with high-quality redshifts detected within 20″ of each quasar targeted in this work. For comparison, measurements from other

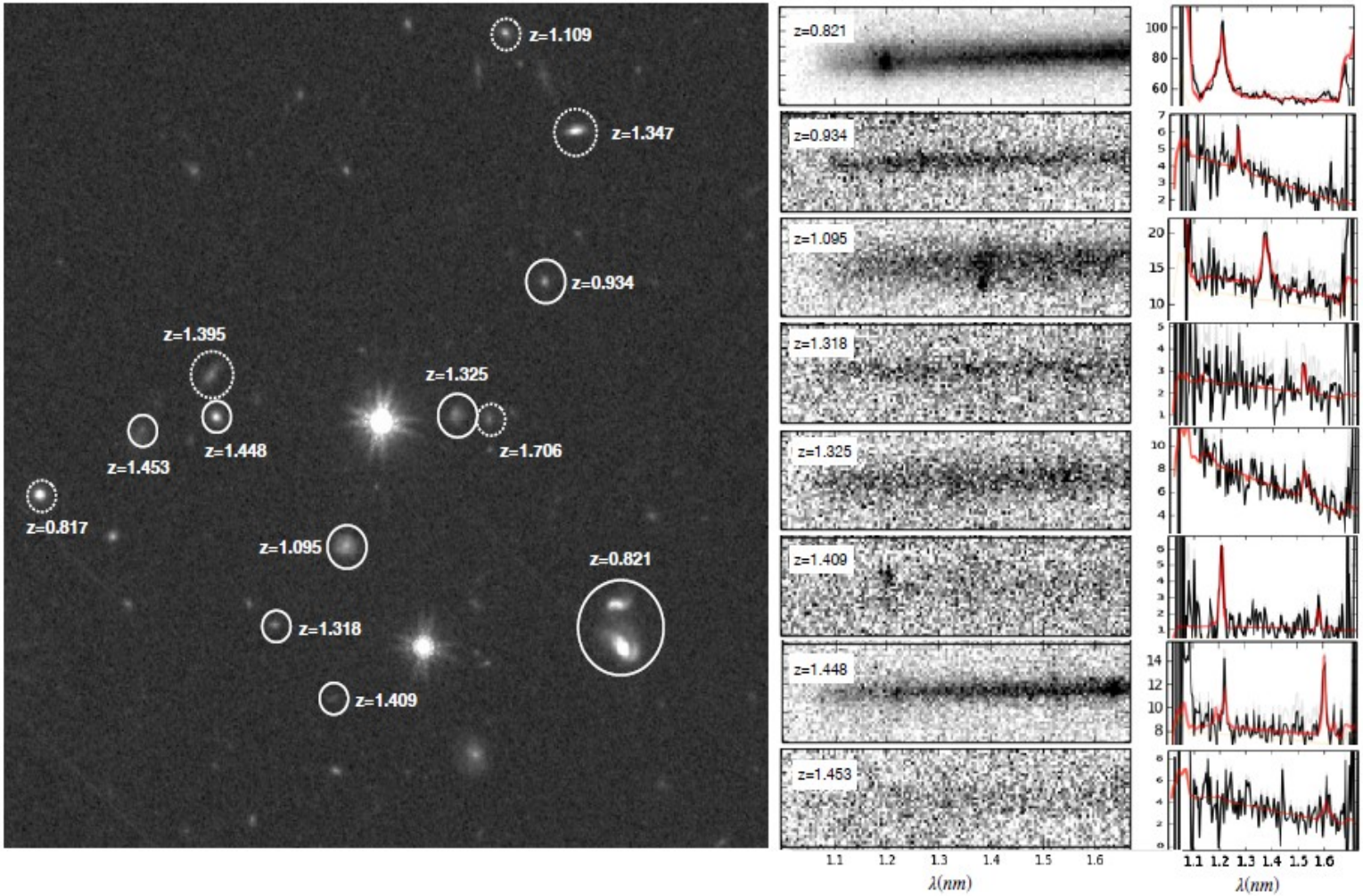
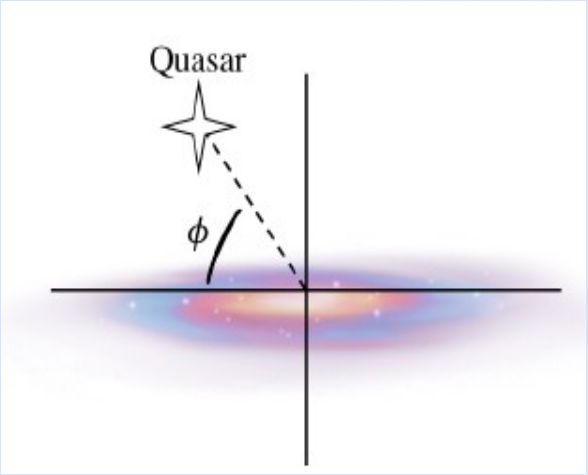


FIG. 4.— WFC3/IR observations of galaxies with redshifts matching six strong Mg II absorption systems detected in the spectrum of quasar SDSS J083852.05+025703.7 (field 2, $z_{QSO} = 1.771$). Left: The F140W direct image of the field centered on the quasar, cropped to a field of view of 0.8'×0.8'. The nearest galaxies with well-determined redshifts are labeled. Solid circles indicate galaxies matched to absorption; dashed circles indicate galaxies with well-determined redshifts but are not considered a match to absorption due to the redshift difference. The 2D (middle panel) and 1D (right panel) G141 grism spectra for the absorption-matched galaxies labeled in the image of the field. In the 1D spectra, observations are presented in black with the best-fit model overlaid in red. The Hα emission line is clearly visible for the galaxies with redshifts below $z = 1.6$. Only one of the two acquired grism spectra for the pair of interacting galaxies at z=0.821 is shown, but both spectra indicate the same redshift with high signal to noise.



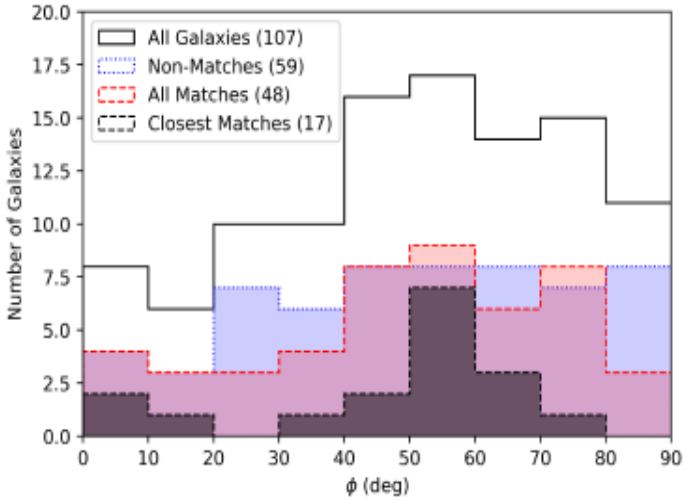
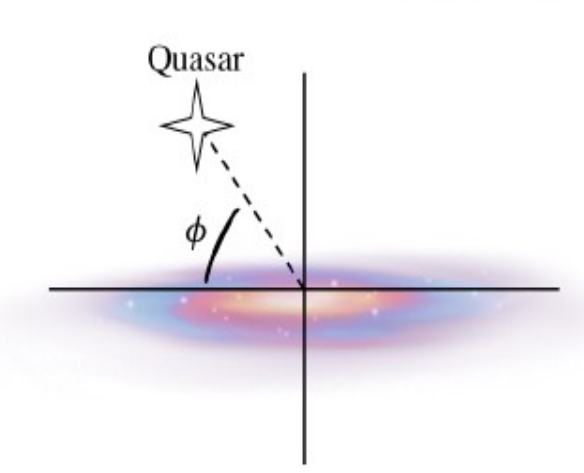
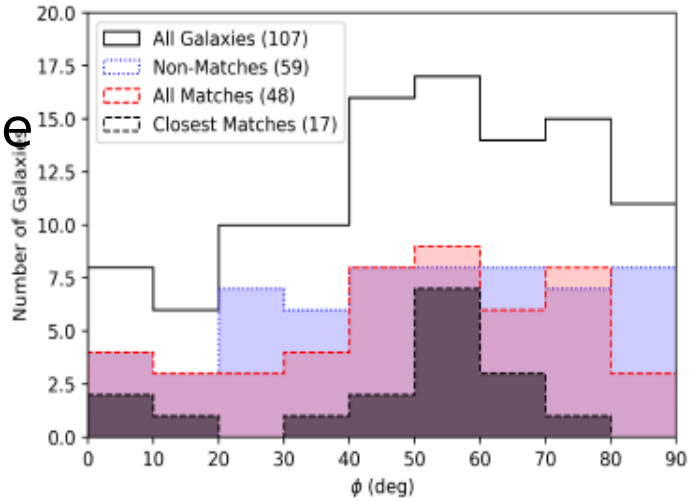


FIG. 13.— The azimuthal angle (ϕ) distribution of background quasar sightlines probing foreground galaxies in our sample. The plot includes galaxies not matched to Mg II absorption (blue), all cases where a galaxy matches to a Mg II detection (red), and a subset of the latter that includes only the matched galaxies with the closest projected separation of all possible pairs (black, filled).

Пики на 0 и $60^{0.}$
Интерпретация:
collimated winds form under-dense cavities along the minor axis





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Линии:
Z~0.4 (штрих)
и
Z>1(вверху)

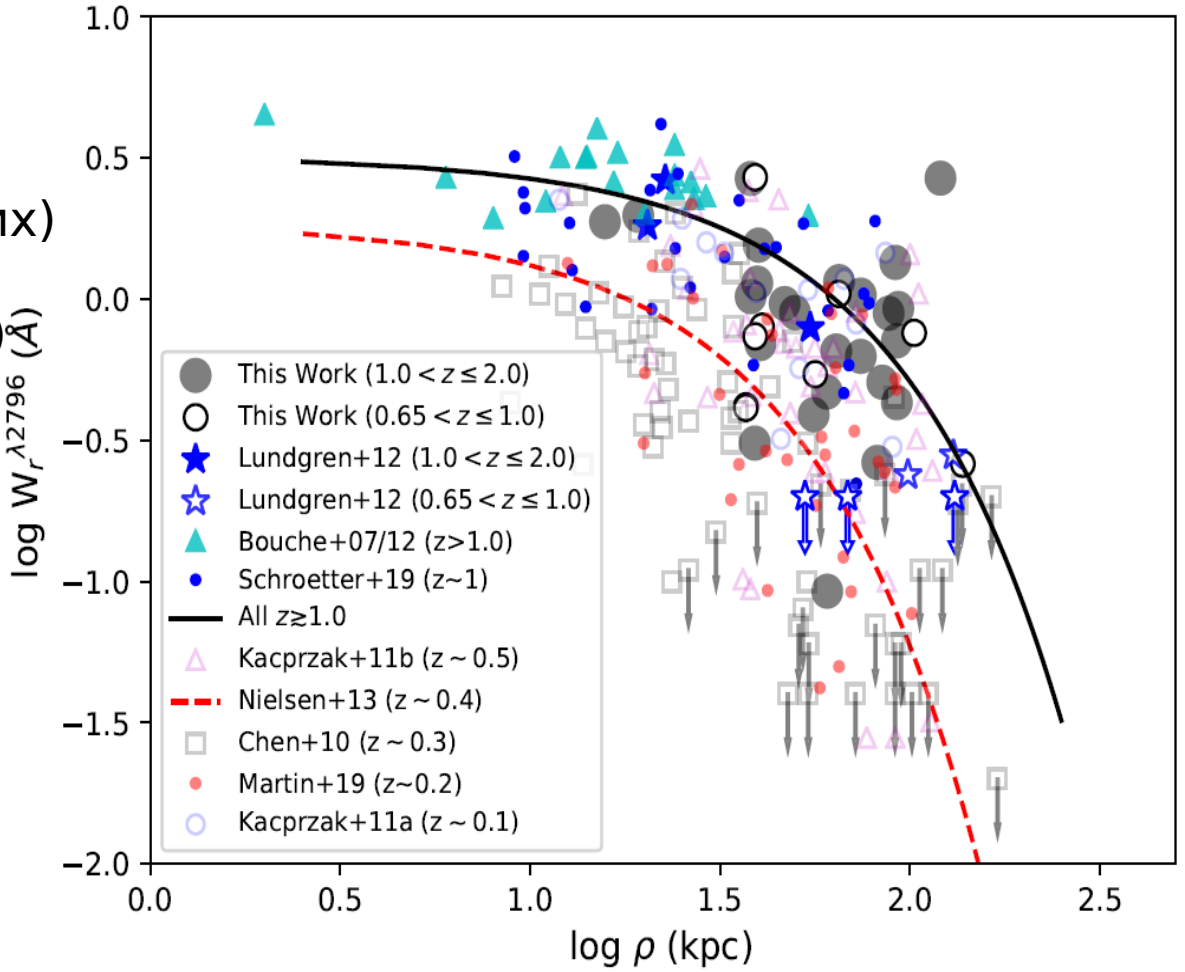

FIG. 9.— The Mg II 2796Å absorber rest-frame equivalent width (W_r) plotted versus impact parameter (ρ) for galaxies matched to Mg II absorption in this work, shown in comparison to other surveys in the literature. A log-linear fit to the

The mean SFR within 150 kpc
for galaxies matched
to a Mg II detection.

Σ_{SFR} также выше:

0.30pm 0.06 M/yr/kpc^2, compar

0.140pm0.02 M/yr/kpc^2 for gala

without a Mg II detection

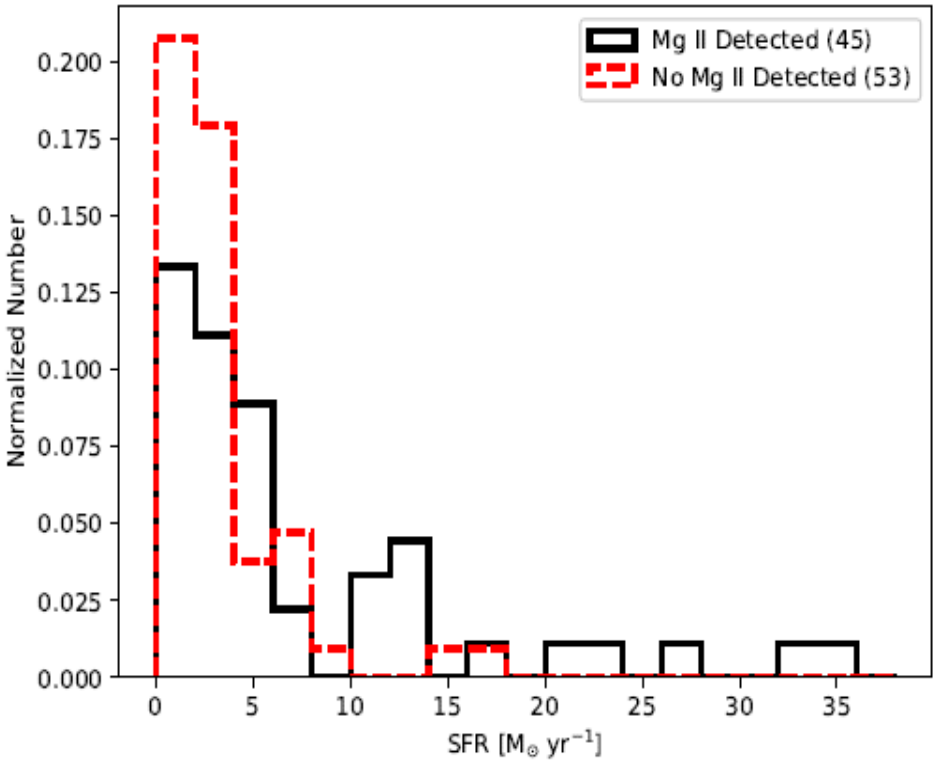

FIG. 11.— The star formation rate distribution for galaxies with Hα emission measurements above our detection threshold and within 150 kpc of the quasar sightline. Galaxies with coincident Mg II absorption in the quasar sightline have significantly higher average SFRs and trace a significantly different distribution of SFRs compared to galaxies without Mg II detections, as quantified with $> 99\%$ probability by a K-S test.

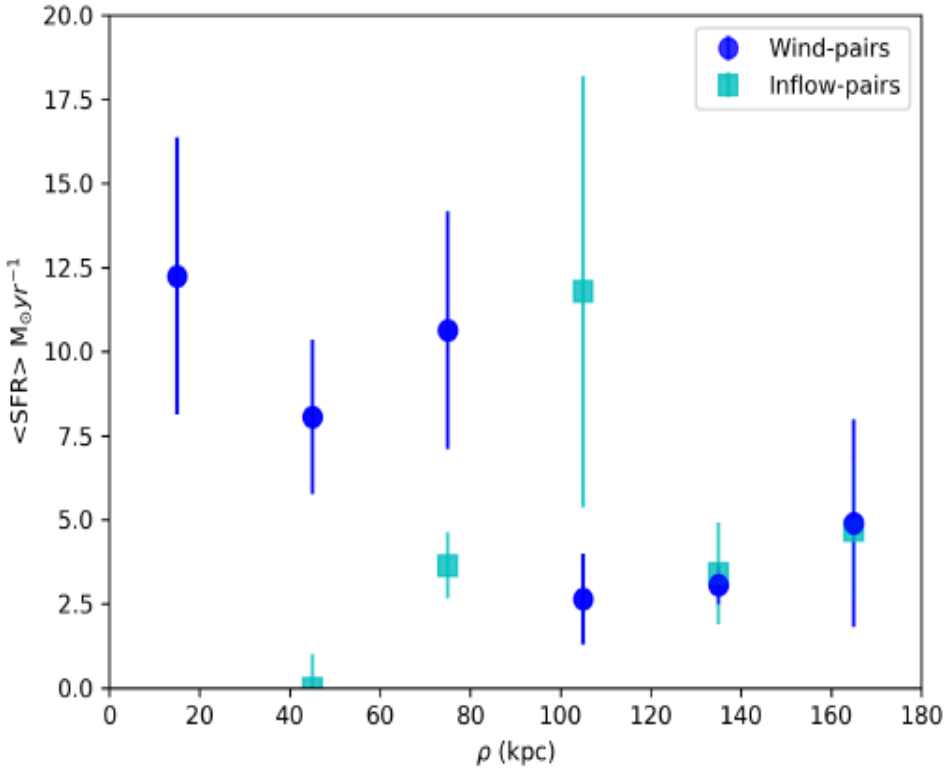

FIG. 18.— The mean SFR of galaxies matched to Mg II absorption, shown as a function of impact parameter (ρ). The data are subdivided by azimuthal angle to wind-pairs ($\phi \geq 40^\circ$) and inflow-pairs ($\phi < 40^\circ$). Wind-pairs with $\rho \lesssim 80$ kpc have significantly higher mean galaxy SFRs compared to inflow-pairs at similar impact parameters and wind-pairs at $\rho > 100$ kpc.

Основные выводы

- 89% of the targeted Mg II absorption systems were condently matched to at least one galaxy with

$\Delta z/(1 + Z_{MgII}) < 0.006$ within 200 kpc.

- Nearly half of the absorbers in our targeted sample matched in redshift to two or more galaxies, and the **mean Mg II rest-frame equivalent width of absorbers matched with groups is greater than that of absorbers matched to isolated galaxies.**
- The sample of galaxies matched to Mg II absorption were found to have a significantly higher mean star formation rate, and a marginally higher mean SFR, compared to galaxies that were not matched to Mg II absorption.
- Most of the galaxy absorber pairs were detected within 50^0 of the minor axis, suggestive of an origin in star formation-driven outflows.
- We also find that the signature of wind driven outflows in the azimuthal angle distribution is more