Galactic Outflows and the Morphology of Star Formation at $1 < z < 1.5$

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Introduction

Intense star formation in galaxies results in powerful, galactic-scale outflows of gas. These outflows regulate star formation by heating or expelling gas from the galaxy, but the primary driving mechanisms are still uncertain.

We investigate the connection between galactic outflows and the morphology of star formation using two independent data sets covering a sample of 25 galaxies between $1 < z < 1.5$, with a mean mass of 10^{10} $M_\odot$ and mean star formation rate of 10.4 $M_\odot$ yr^{-1}.

- HST/WFC3 (rest-frame optical): Low spectral resolution, high spatial resolution spectroscopy yielding Hα emission line maps used to measure spatial extent and strength of star formation
- Keck/DEIMOS (rest-frame near-UV): Fe II and Mg II absorption lines, which provide constraints on the intensity and velocity of the outflows.

We compare the outflow properties with the star formation rate and star formation rate surface density inferred from the Hα emission line maps. The combination of rest-frame UV spectroscopy and Hα mapping at high spatial resolution enables direct comparisons between star forming regions and the outflows they drive.

Future facilities such as the *JWST* and the upcoming ELTs will extend these studies to lower masses and star formation rates, probing galactic feedback across orders of magnitude in galaxy properties.

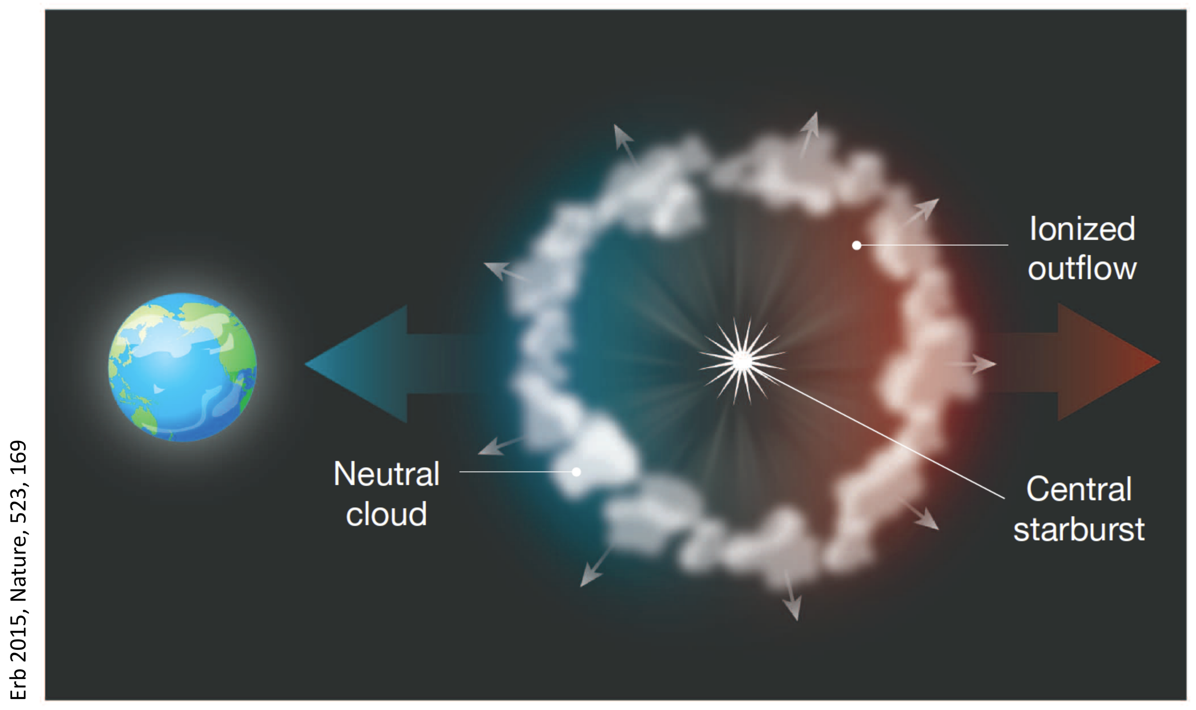

Figure 1: Cartoon of a galactic outflow. Energy and momentum from the central starburst drive gas outward. The absorption lines we observe associated with this outflow are blueshifted (see Figure 2).

Outflow Velocities

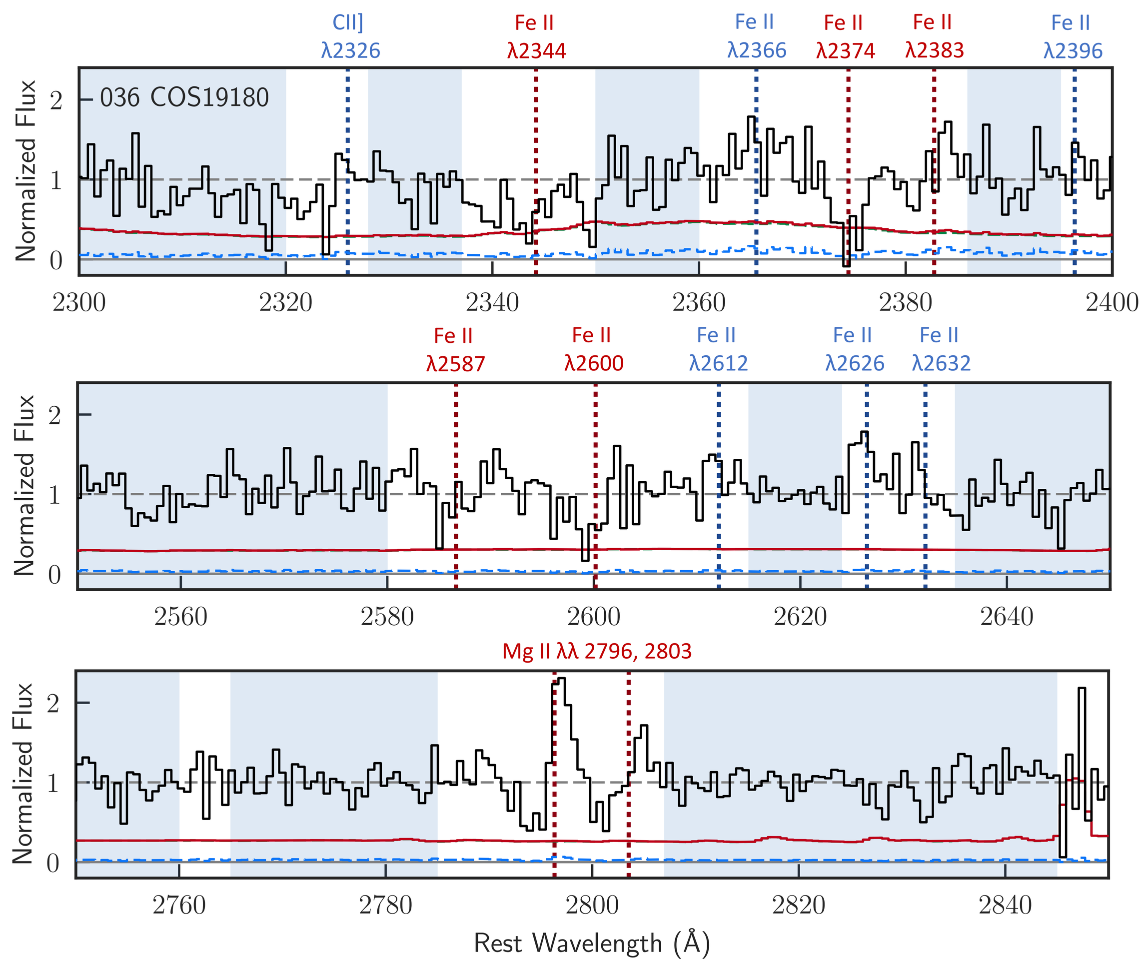

Figure 2: A Keck/DEIMOS spectrum of a galaxy in the COSMOS field (ID no. 19180) at z = 1.21 with a mass of 10^9 $M_\odot$. The shaded blue regions are the windows used for continuum fitting. Three error spectra are shown: the 1σ error spectrum (green dashed line) and uncertainty in the continuum fit (blue dashed line) are summed in quadrature to obtain the final error spectrum (solid red line). The vertical dotted lines show expected spectral features: absorption lines in red, and Fe II fine structure emission lines in blue. The blueshifted centroids indicate a galactic outflow.

Hα Emission Line Maps and Star Formation Rates

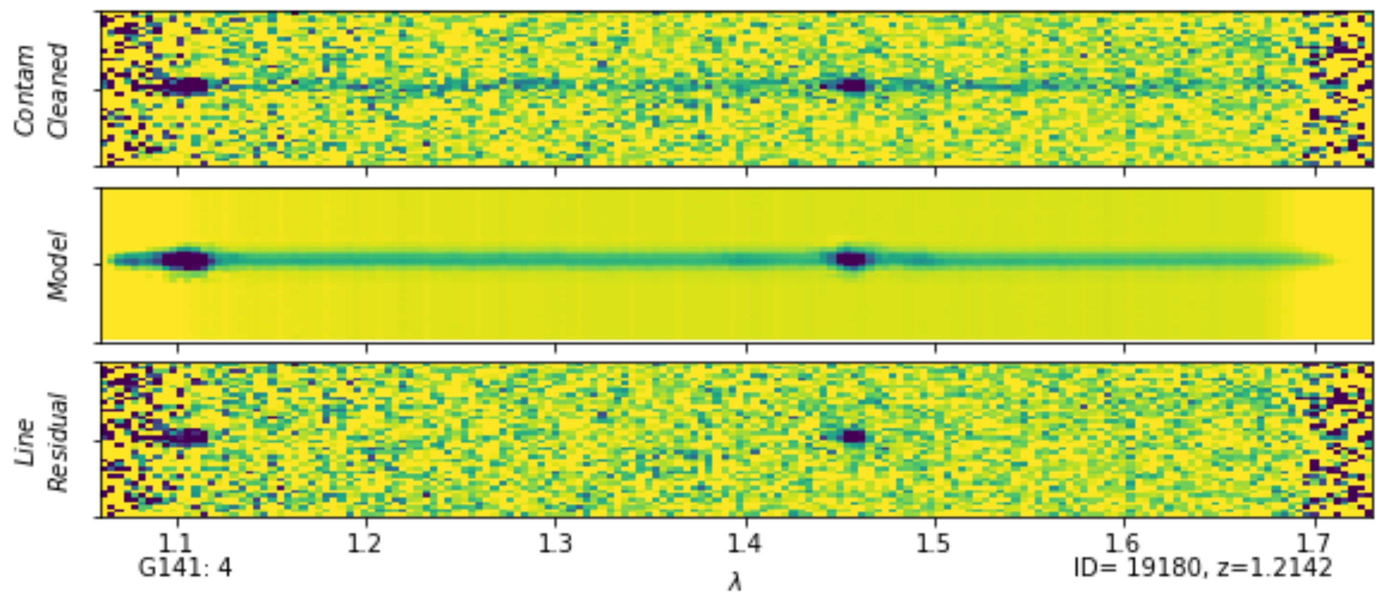

Figure 3: A 2D spectrum taken by the WFC3/G141 grism on *HST* of COS 19180. Hα and [OIII] emission lines are present at 1.45 and 1.11 μm respectively. The *Grizli*[1] pipeline produces a fully reduced 2D spectrum (top panel), model (middle panel), and subtracts the continuum to produce a line-only spectrum (bottom panel).

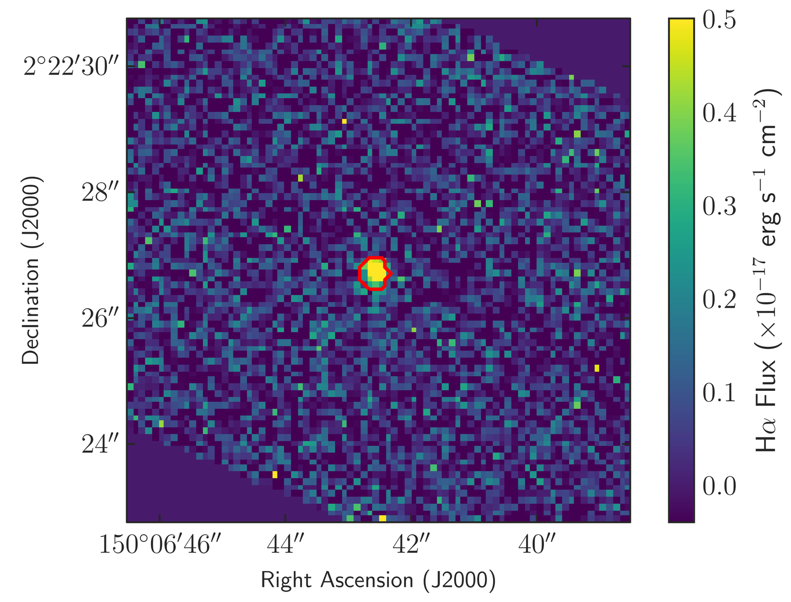

Figure 4: The final product of the *Grizli* pipeline, an Hα emission line map showing the spatial distribution of star formation. The above map shows Hα emission from COS 19180. The red contour shows the 0.19 ± 0.04 $arcsec^2$ (13.8 ± 2.6 kpc^2) region of highest Hα S/N within which we measure an SFR of 6.6 ± 0.6 $M_\odot$ yr^{-1} and an SFR surface density of 0.48 ± 0.04 $M_\odot$ yr^{-1} kpc^{-2}.

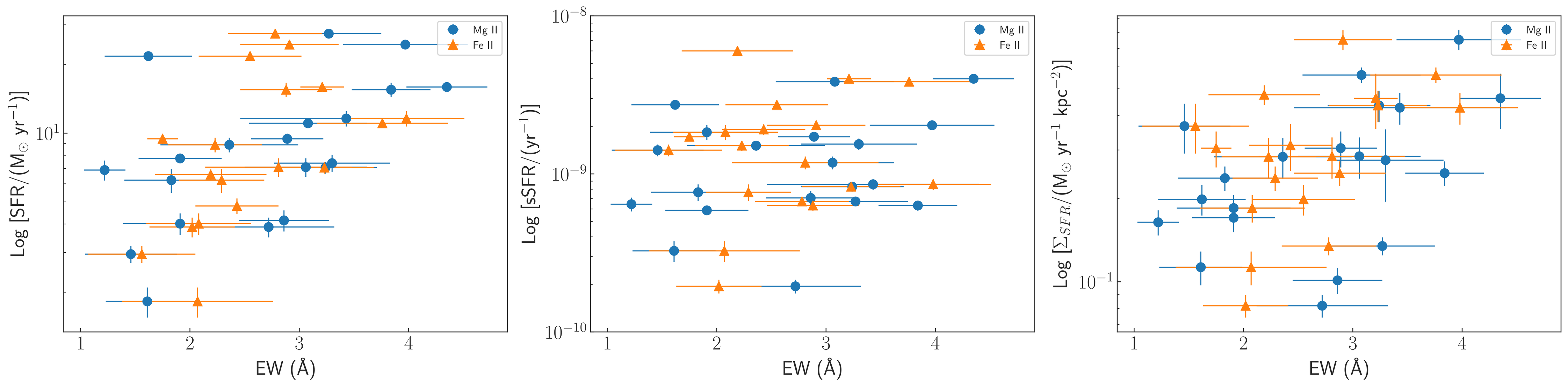

Figure 5: Fe II and Mg II equivalent width from Keck/DEIMOS plotted against star formation rate, specific star formation rate, and star formation rate surface density. We find a correlation above the 3σ level between Mg II EW and SFR.

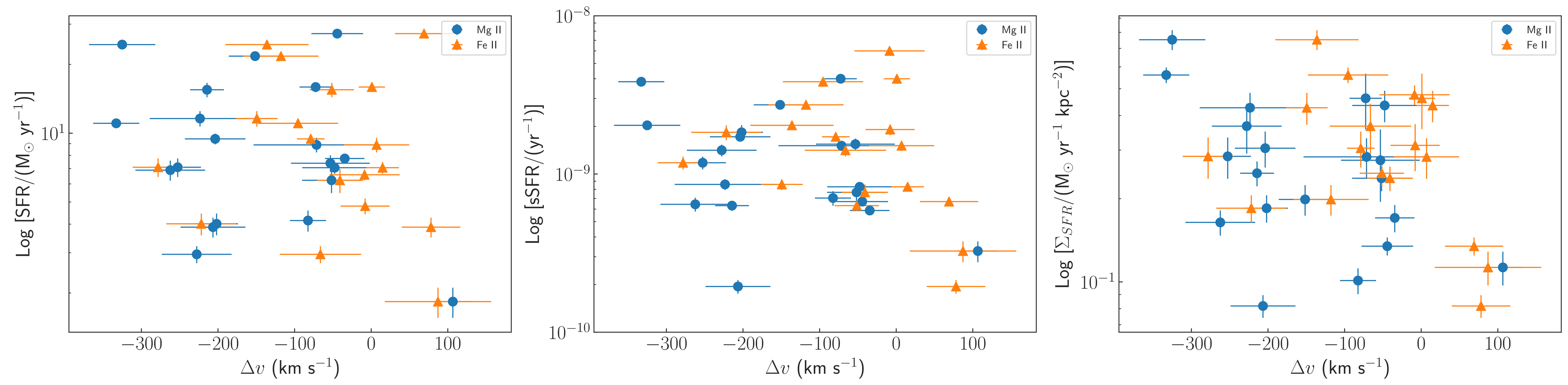

Figure 6: Fe II and Mg II centroid velocities plotted against star formation rate, specific star formation rate, and star formation rate surface density. We do not find any significant correlations.

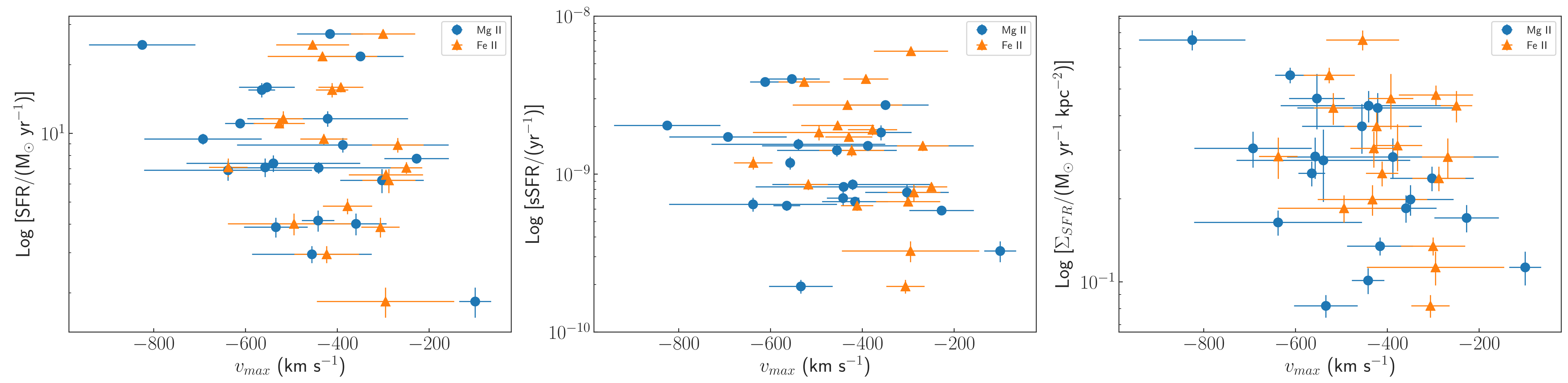

Figure 7: Fe II and Mg II maximum velocities plotted against SFR, specific SFR, and SFR surface density. The maximum velocity is the velocity at which the blue side of the absorption line reaches the continuum. We do not find any significant correlations.

Summary

We compare outflow velocities and equivalent widths from Fe II and Mg II absorption lines to star formation rates, specific SFRs, and SFR surface densities. We show preliminary results and find a significant correlation between Mg II EW and SFR. This work is a demonstration of technique, which can be extended using future telescopes like *JWST* and ground-based ELTs. This, and future research, will help to shed light on the feedback processes which influence star formation in early galaxies.

Acknowledgements

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[1] Special thanks to Dr. Gabriel Brammer (STScI) for his input with *Grizli* (https://grizli.readthedocs.io/en/master/)