

# Galactic-Scale Star Formation-Driven Outflows at $1 < z < 1.5$ in the 3D-HST Survey

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## Abstract

Intense star formation in galaxies results in powerful, galactic-scale outflows of gas. Because stars form from gas, these outflows have a strong effect on the evolution of galaxies, but the intricacies of the process are still unknown. We investigate the connection between galactic outflows and the structure of galaxies using two independent data sets covering a sample of galaxies in the early universe. The Wide Field Camera 3 grism on the Hubble Space Telescope (HST) provides high spatial resolution spectroscopy yielding maps of the extent and strength of star formation, while absorption line spectra from the Keck Telescope at Mauna Kea provide the intensity of and velocity of the outflows. We present the correlations between star formation rate and outflow velocity, and how the outflow properties relate to the structure of the galaxies.

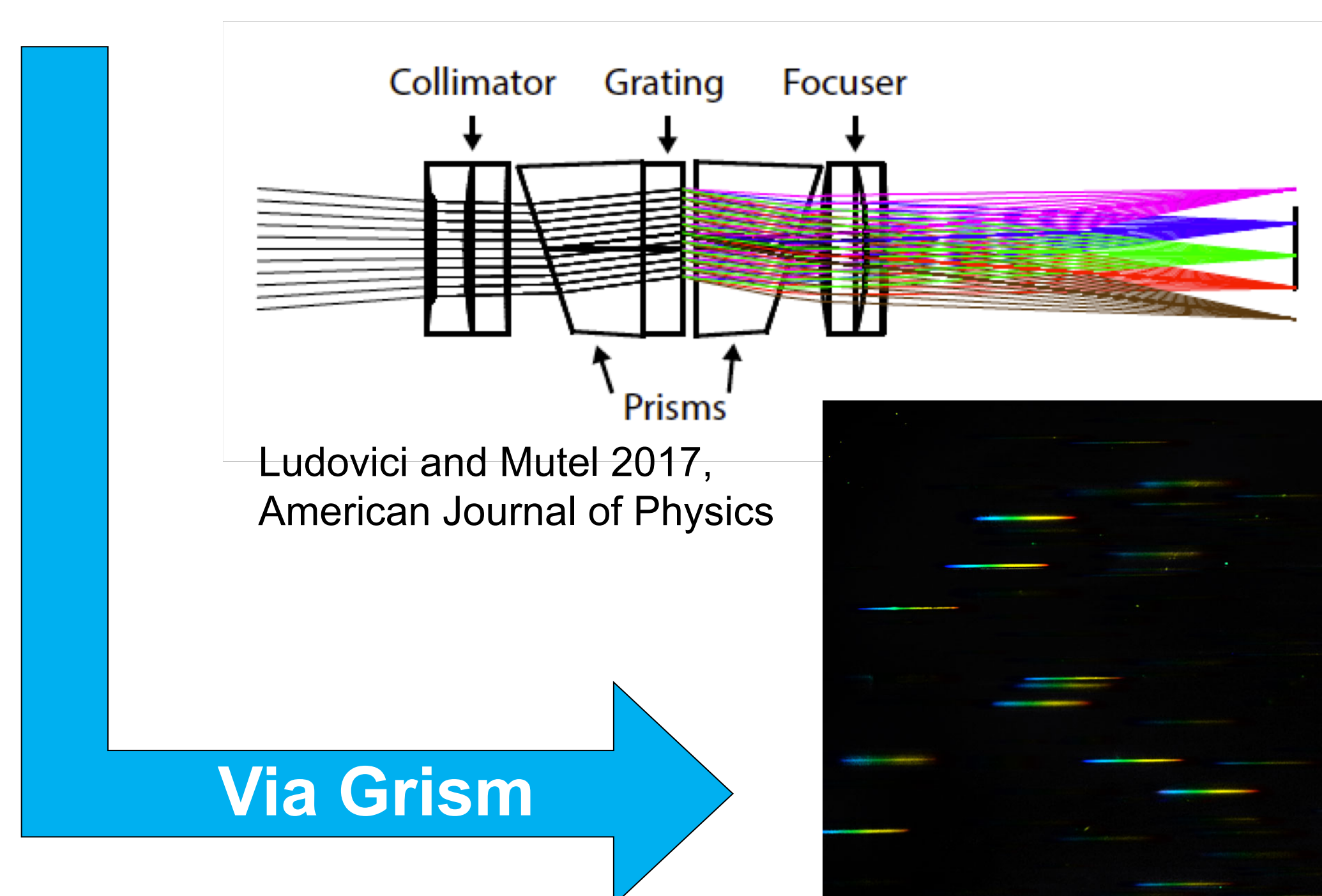
## Introduction

Using Hubble Space Telescope to take images of galaxies when the universe was half its current size.

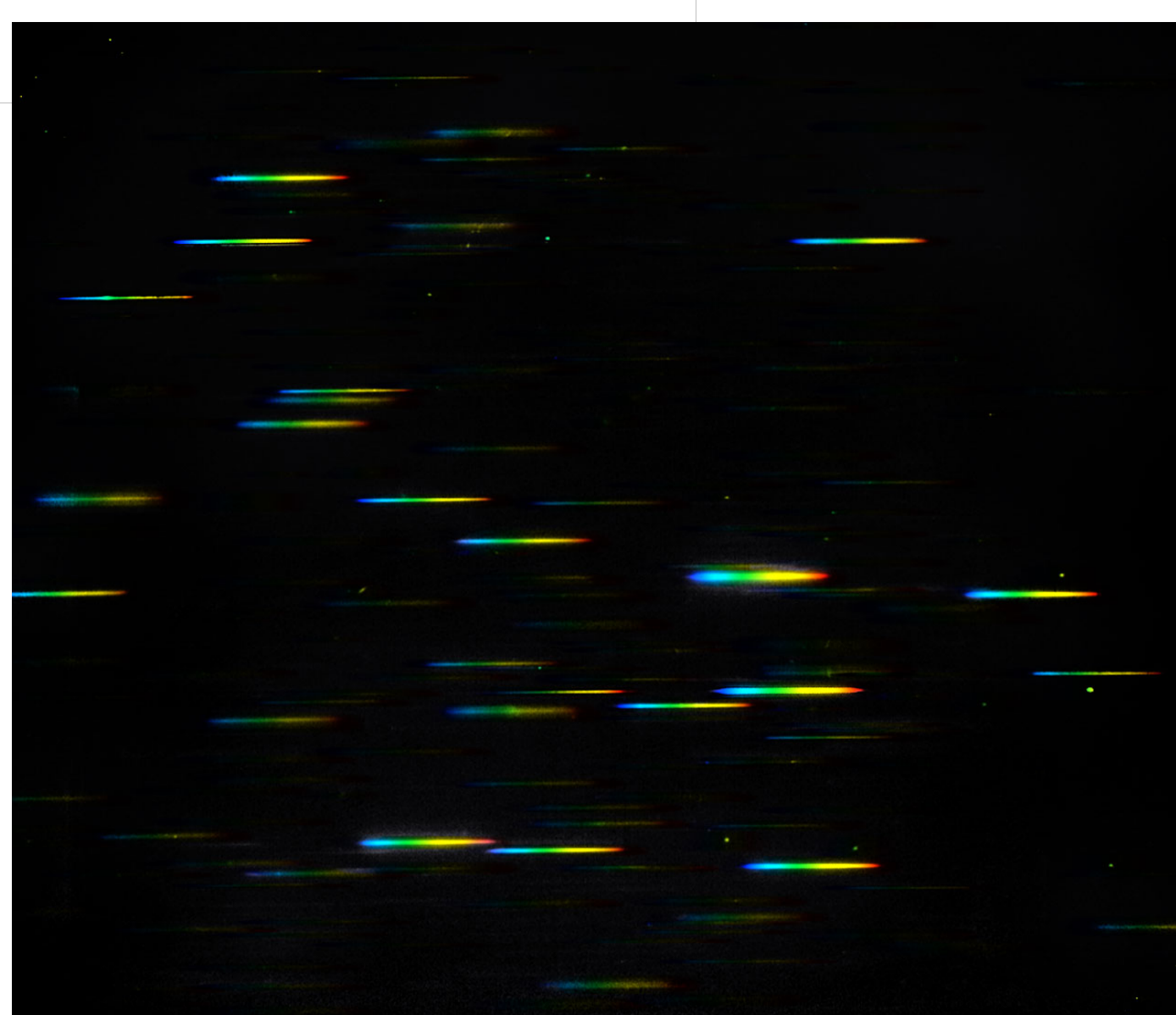


HST eXtreme Deep Field

The grism forms a spectrum for each galaxy in the image.



Ludovici and Mutel 2017, American Journal of Physics

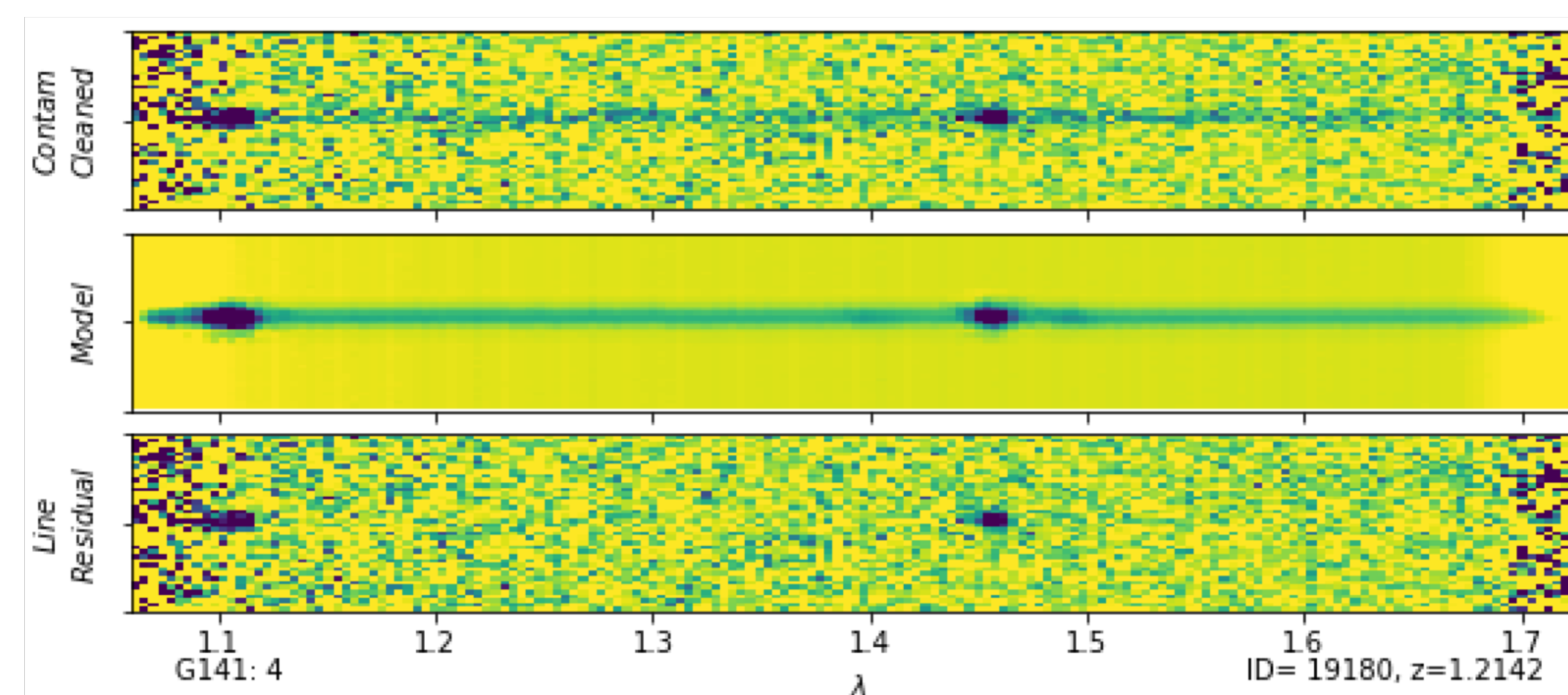


XDF and grism concept courtesy NASA, ESA & Hubble

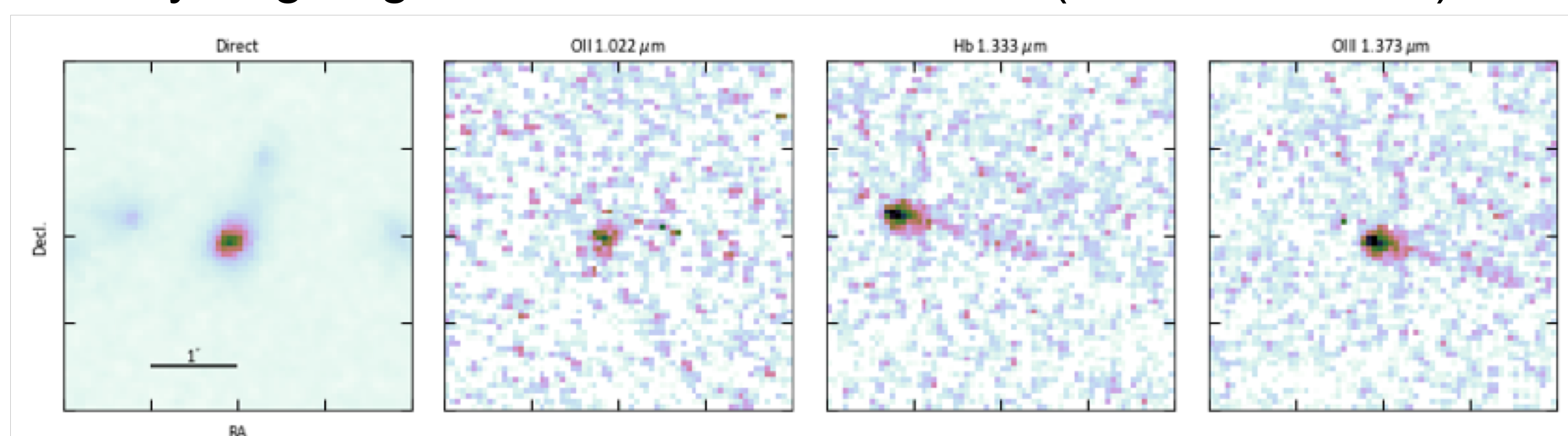
## Measuring Emission Line Sizes

Using the Grism image, we create a model of the spectrum from each galaxy which best fits the observed data.

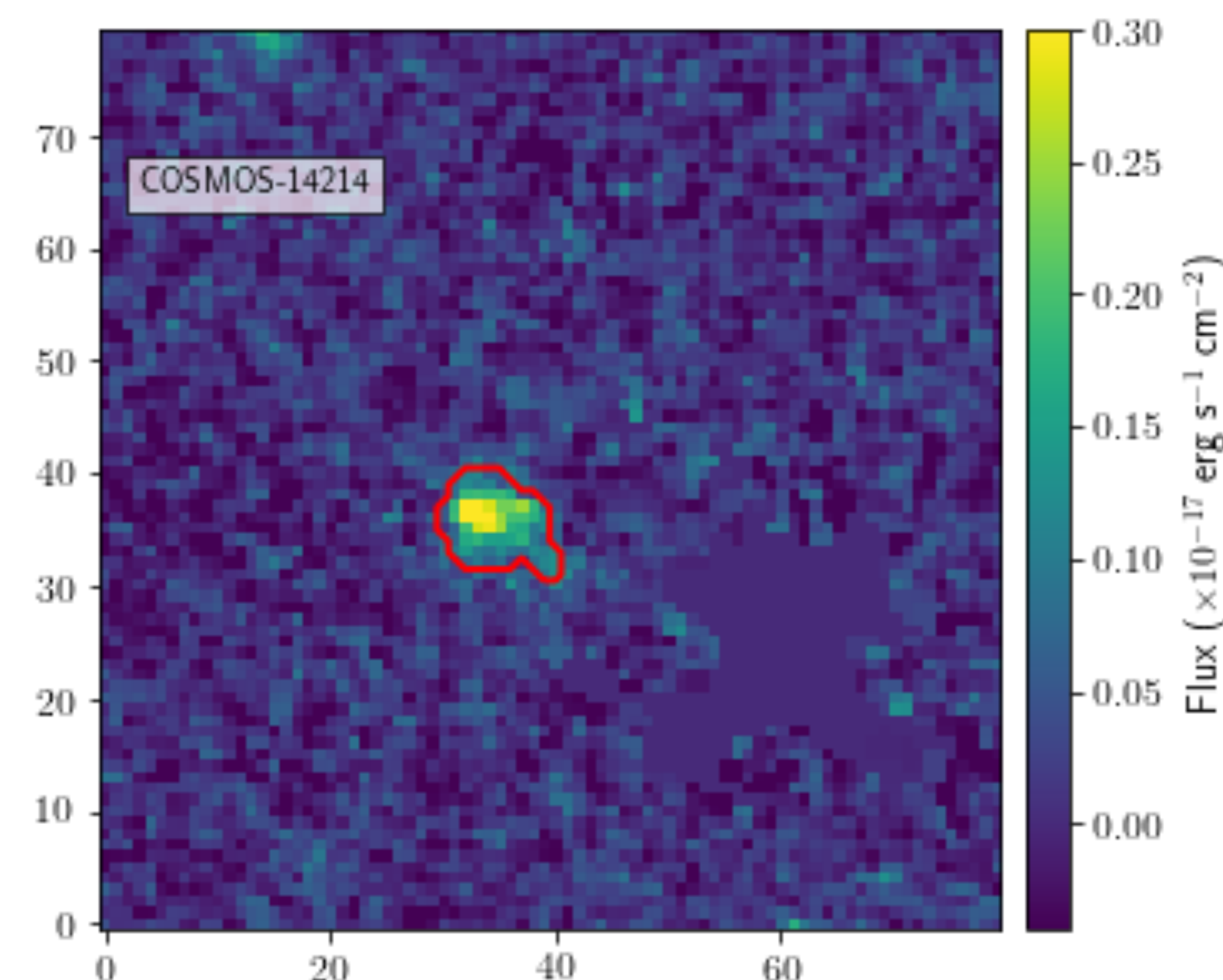
The green image below shows the actual spectrum in the top row, the model of the galaxy in the center row, difference between the two images at the bottom. This plot shows relative position as a function of wavelength, with the color scheme representing intensity of the emission.



From here, we make emission line maps that show the distribution of hydrogen gas ionized by newly-formed massive stars. We can convert the luminosity of the hydrogen gas to a star formation rate (Kennicutt 1998).

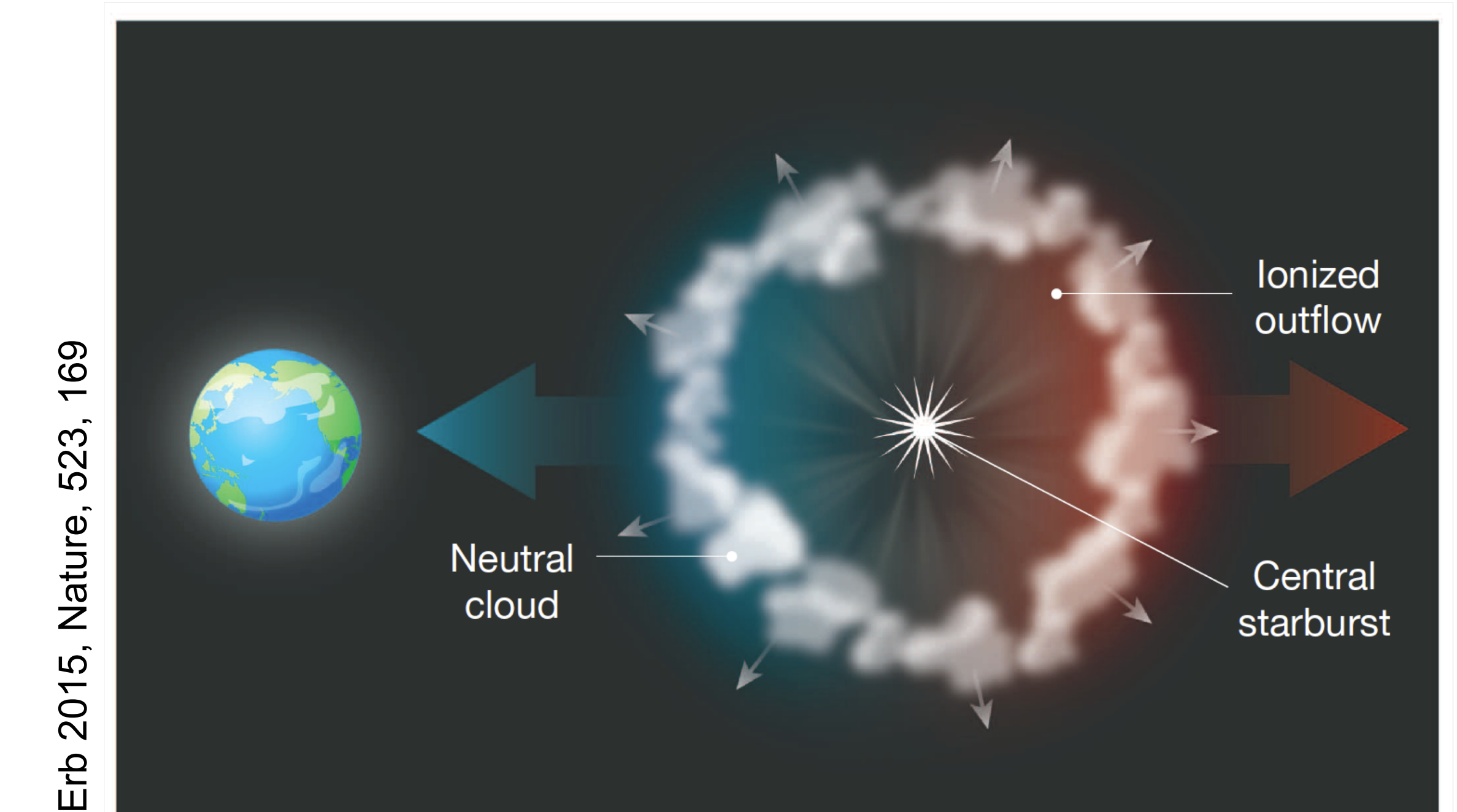


We measure the area of the emission line on the sky to calculate the star formation rate per unit area.

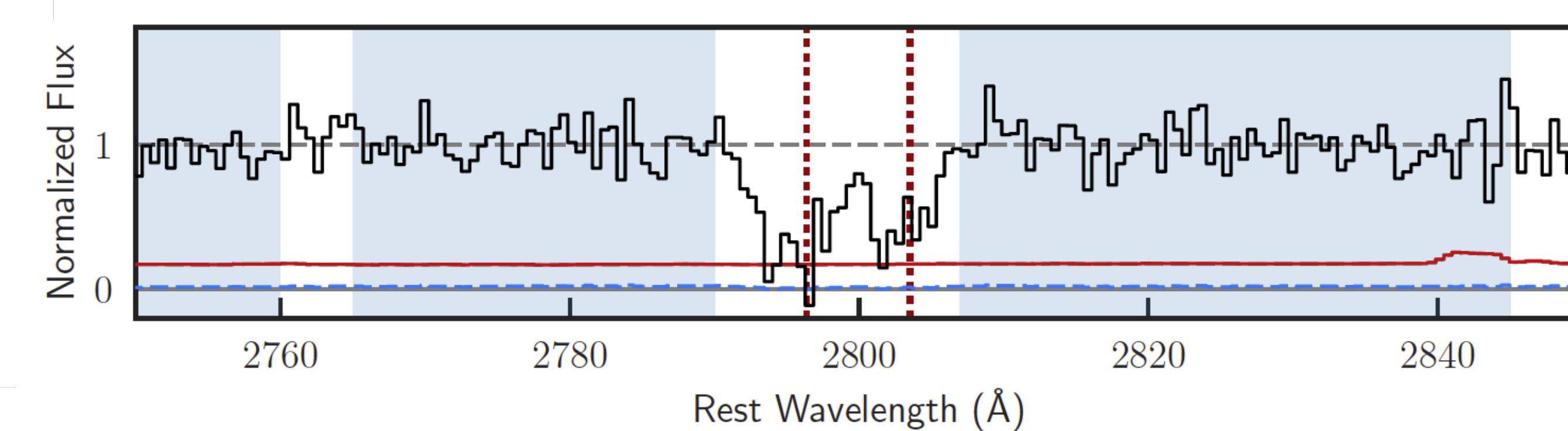


## Comparing with Absorption Spectra

Typical star-forming galaxies in the early universe have outflows of neutral hydrogen gas which absorbs radiation from stars. The absorption lines we see from this gas allow us to measure the velocities of the outflows.



We are currently in the process of comparing the emission lines in the Grism images with the absorption line spectra from Keck. In the bottom-center image, we see strong H $\alpha$  emission combined with absorption lines blueshifted from their rest wavelengths (red dashed lines), indicative of a galactic outflow.



## Summary

Our work focuses on the connection between intense star formation and large scale galactic outflows. When massive stars form, they expel the surrounding gas into the intergalactic medium. This may result in a reduction of star formation leading to fewer outflows. This work will help to shed light (no pun intended) on the feedback process which influences star formation in these early galaxies.

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