Visualizing HII Abundance in FIRE Data

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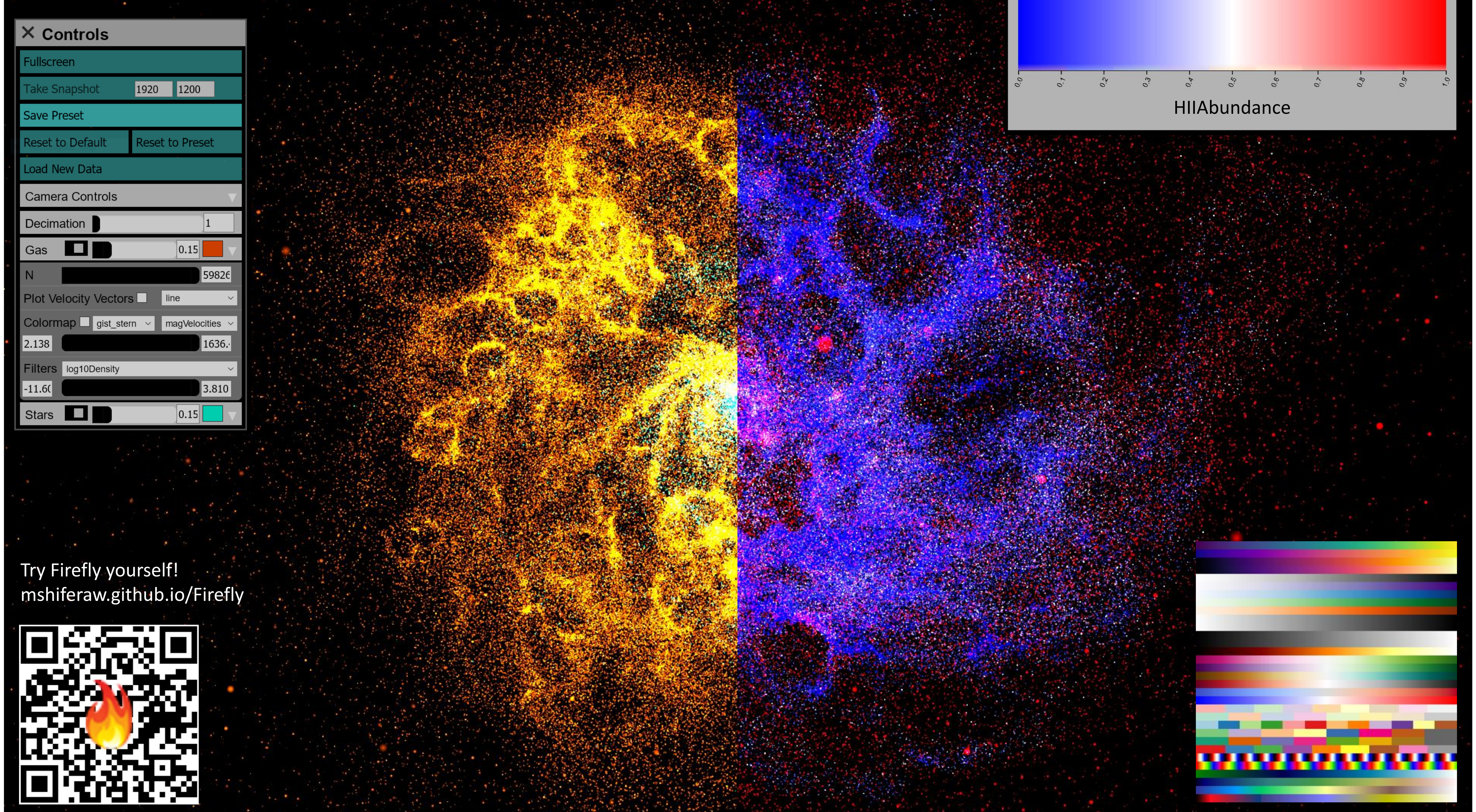
Firefly: An Interactive Web-Based Visualization Application



Left: Gas particles are colored orange, and stars light blue. **Right:** Gas only, with a BWR divergent colormap applied to HII abundance.

Colormaps: 32 different options.

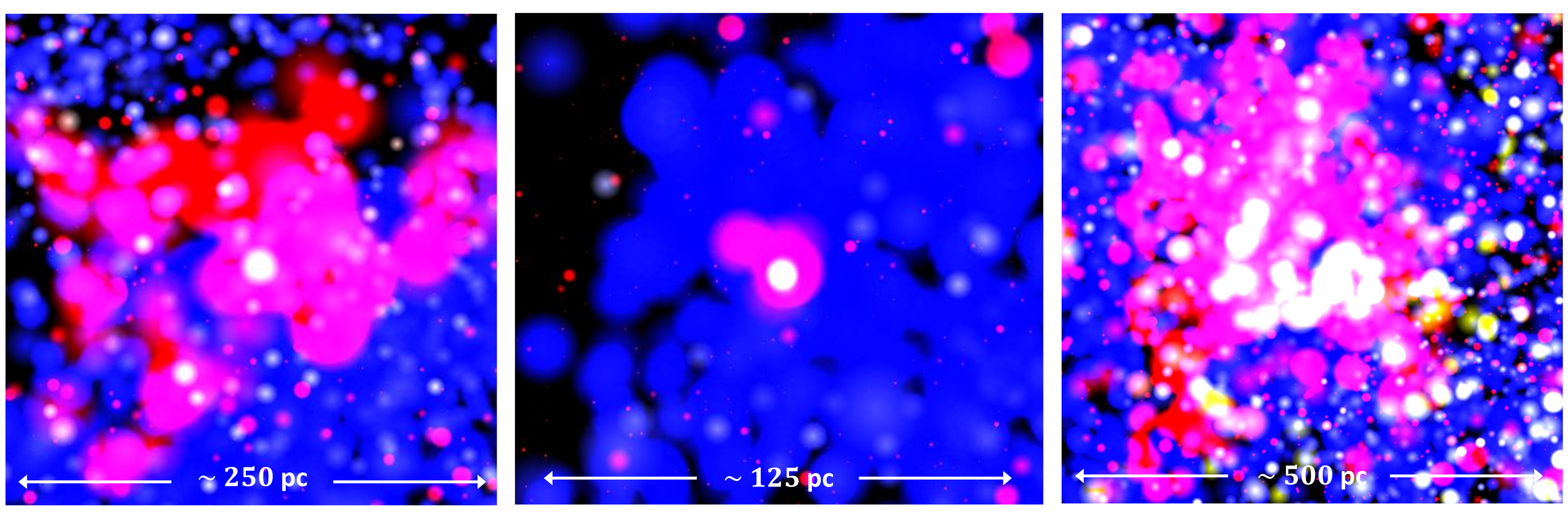
Visualizing FIRE Galaxies

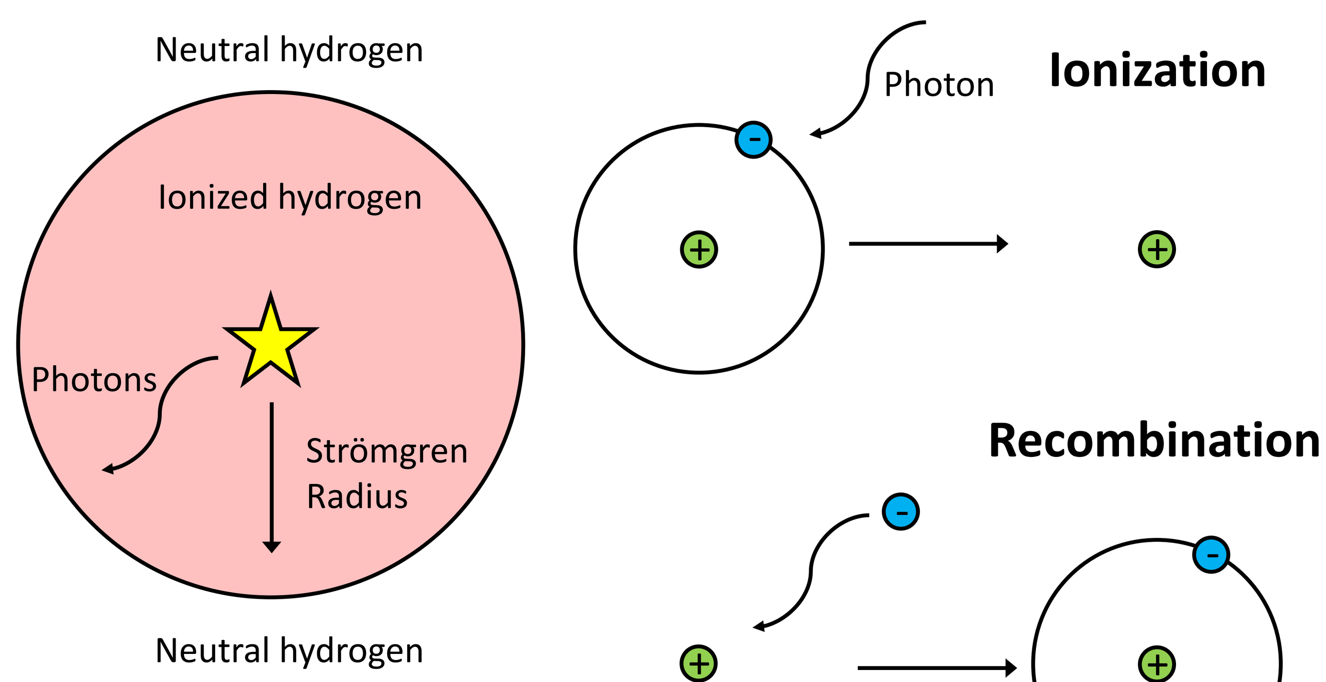
We have used cosmological zoom-in simulation data from the Feedback in Realistic Environments (FIRE) Project to examine how ionized hydrogen (HII) abundance spatially relates to young stars. We focus on a Milky Way-mass, isolated spiral galaxy with stars and gas only.

Developing Colormaps

Our team has created Firefly, a tool for interactively exploring particle-based data by zooming in, rotating around, and more. We have used Firefly to gain an intuitive understanding of the galaxy simulation, and have also developed functionality to apply one colormap to each particle type based on a certain attribute. Here, we apply a blue-white-red (BWR) colormap to HII abundance in gas.

Using Firefly to Explore HII Regions Around Young Stars





Using CHIMES, a chemistry module, we are able to predict HII abundance in gas. Here, applying the BWR colormap to HII abundance reveals “bubbles” of highly ionized gas that have formed around stars < 10 Myr, which are colored yellow. Due to an additive blending function, red gas on blue may appear pink, and yellow stars white. Pictured are two lone stars and a star cluster.

Modeling these HII Regions using the Strömgren Radius

The Strömgren Radius describes spherical HII regions that surround young stars as a result of their UV radiation. This sharp boundary between ionized and neutral hydrogen is found at the point where the enclosed recombination and ionization rates of hydrogen are equal.

$$r_{rec} = r_{ion} \longrightarrow r_{rec} \times V = N$$

$$r_{rec} = n_e n_p \alpha(T) \longrightarrow n_e = n_p = n_H$$

Assume gas is electrically neutral.

$$R_S \simeq \left(\frac{3N}{4\pi\alpha}\right)^{1/3} n_H^{-2/3}$$

N: Ionizing luminosity of star

$\alpha(T)$: Recombination coefficient

n_H: Hydrogen number density

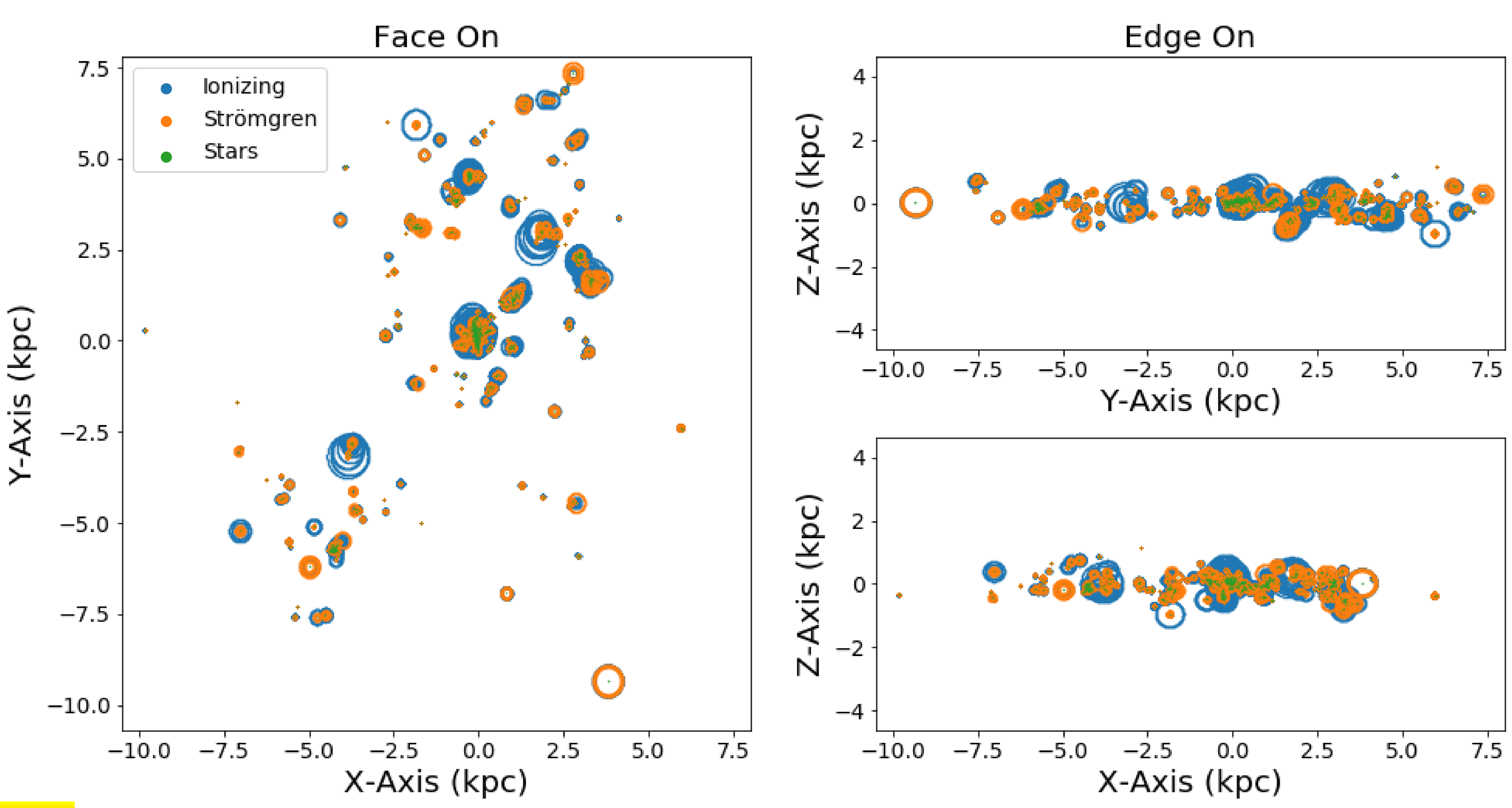
Comparing the Strömgren Radius to HII Regions Found in Simulation Data

Measuring the “Ionizing Radius"

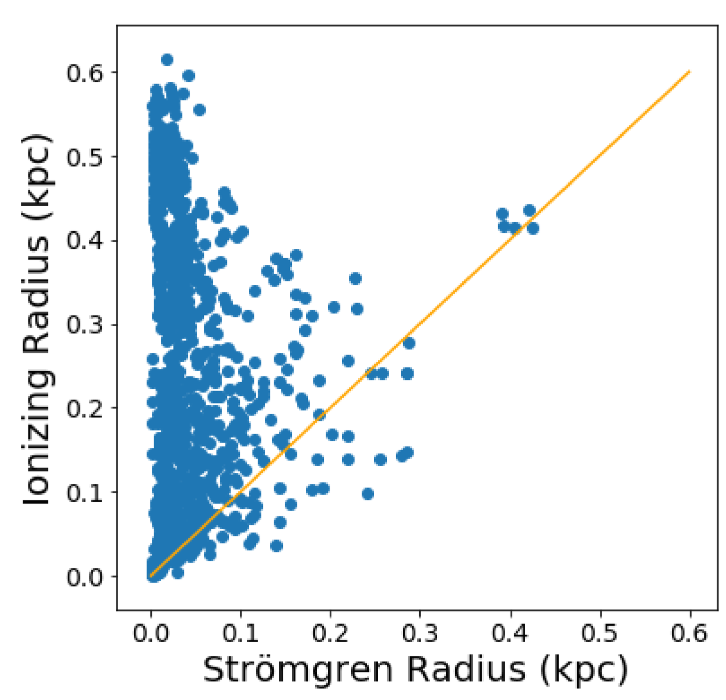
To determine the observed radius, or “Ionizing Radius”, we wrote an algorithm to find where the average enclosed HII abundance around each star reaches below 50%.

Calculating the Strömgren Radius

Per the equation, we used an ionizing luminosity function based on each star’s age and mass, a recombination coefficient of 2.59×10^{-13} cm^3/s, and the average enclosed density within each star’s ionizing radius.

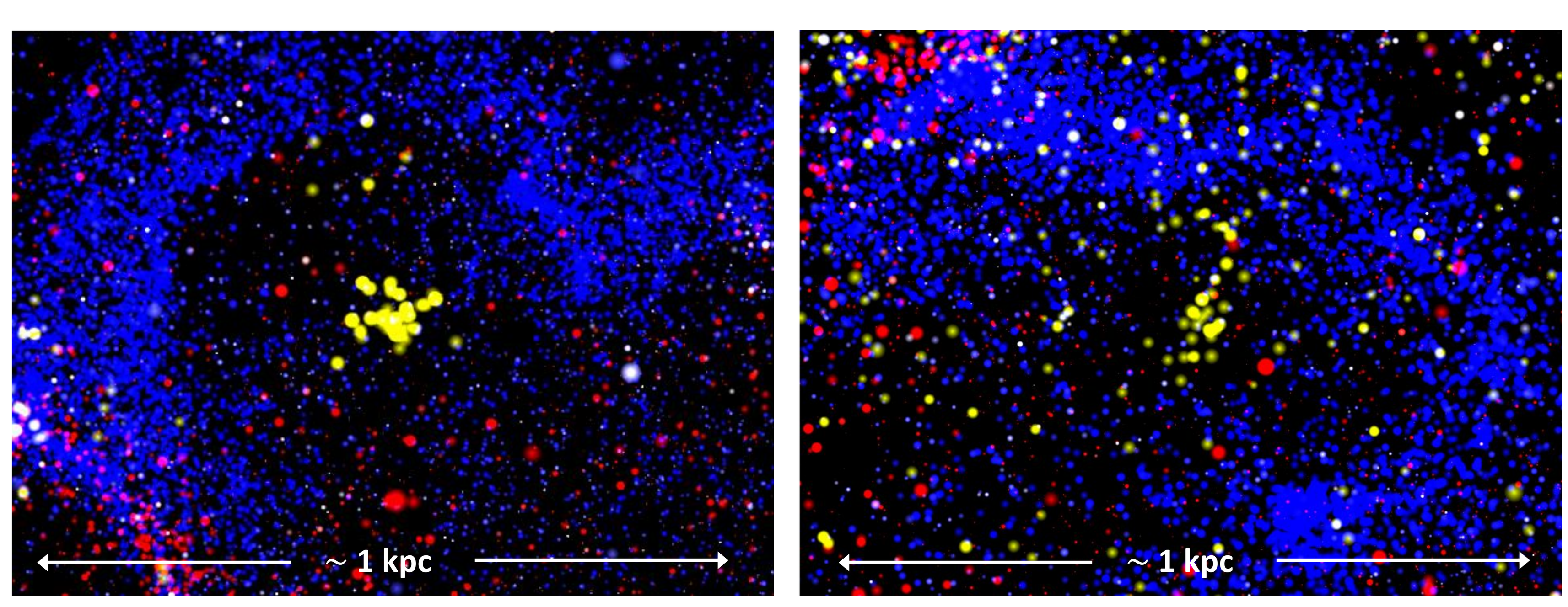


Face-on and edge-on view of Ionizing Radius, Strömgren Radius, and stars. Plotted over xy-, yz-, and xz-axis.



Implications: Stellar Clustering

Our results reveal a limit of the Strömgren Radius: in most cases, the ionizing radius is much larger. This is because young stars tend to form in clusters, and thus have a higher ionizing luminosity than our single star calculations would assume.



Stellar winds blow surrounding gas away. BWR colormap applied to HII abundance. Stars colored yellow.

Future Work

In the future, we hope to also examine H_2 and CO, as well as further improve Firefly.

Acknowledgements

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http://galaxies.northwestern.edu/firefly
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