Light from a strongly magnified galaxy can offer clues to an enigmatic period of the early universe.

Spatially variable Lyα line profiles and environments in a strong LyC leaking galaxy

M. Riley Owens[1], Keunho J. Kim[1], Matthew Bayliss[1], T. Emil Rivera-Thorsen[2], Håkon Dahle[3], Alex Navarre[1], Michael D. Gladders[4], Guillaume Mahler[5,6], Rongmon Bordoloi[7], Soniya Sharma[8], Michael Florian[9], Keren Sharon[10], Gourav Khullar[4,11,12]

[1]Department of Physics, University of Cincinnati, Cincinnati, OH 45221, USA
[2]Department of Astronomy, Oscar Klein Center, Stockholm University, AlbaNova, SE-106 91 Stockholm, Sweden
[3]Institute of Theoretical Astrophysics, University of Oslo, P.O. Box 1029, Blindern, NO-0315, Oslo, Norway
[4]Department of Astronomy and Astrophysics, University of Chicago, 5640 South Ellis Ave., Chicago, IL 60637, USA
[5]Institute for Computational Cosmology, Durham University, South Road, Durham DH1 3LE, UK
[6]Centre for Extragalactic Astronomy, Durham University, South Road, Durham DH1 3LE, UK
[7]Department of Physics, North Carolina State University, Raleigh, NC 27695-8202, USA
[8]NASA Goddard Space Flight Center
[9]Steward Observatory, University of Arizona, 933 North Cherry Ave., Tucson, AZ 85721, USA
[10]Department of Astronomy, University of Michigan, 1085 S. University Ave., Ann Arbor, MI 48109, USA
[11]Kavli Institute for Cosmological Physics, University of Chicago, 5640 S. Ellis Ave., Chicago, IL 60637, USA
[12]Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, 77 Massachusetts Ave., Cambridge, MA 02139, USA

Correspondence: owens2mn@mail.uc.edu

Introduction

By the time the universe celebrated its 1 billionth birthday (now more than 13 billion), it had nearly concluded a period of significant change in its content, which we call the period of reionization. During this time, the first populations of ionizing sources (stars and quasars) ionized the then-neutral content of the universe.

But how this occurred is poorly understood. In the nearby (hence younger) universe, we do not observe enough ionizing radiation escaping sources to explain how ionized our universe is, nor is it feasible to make direct observations of the original ionizing sources responsible for reionization. So, bridging this gap in our knowledge remains an outstanding challenge to modern astronomers.

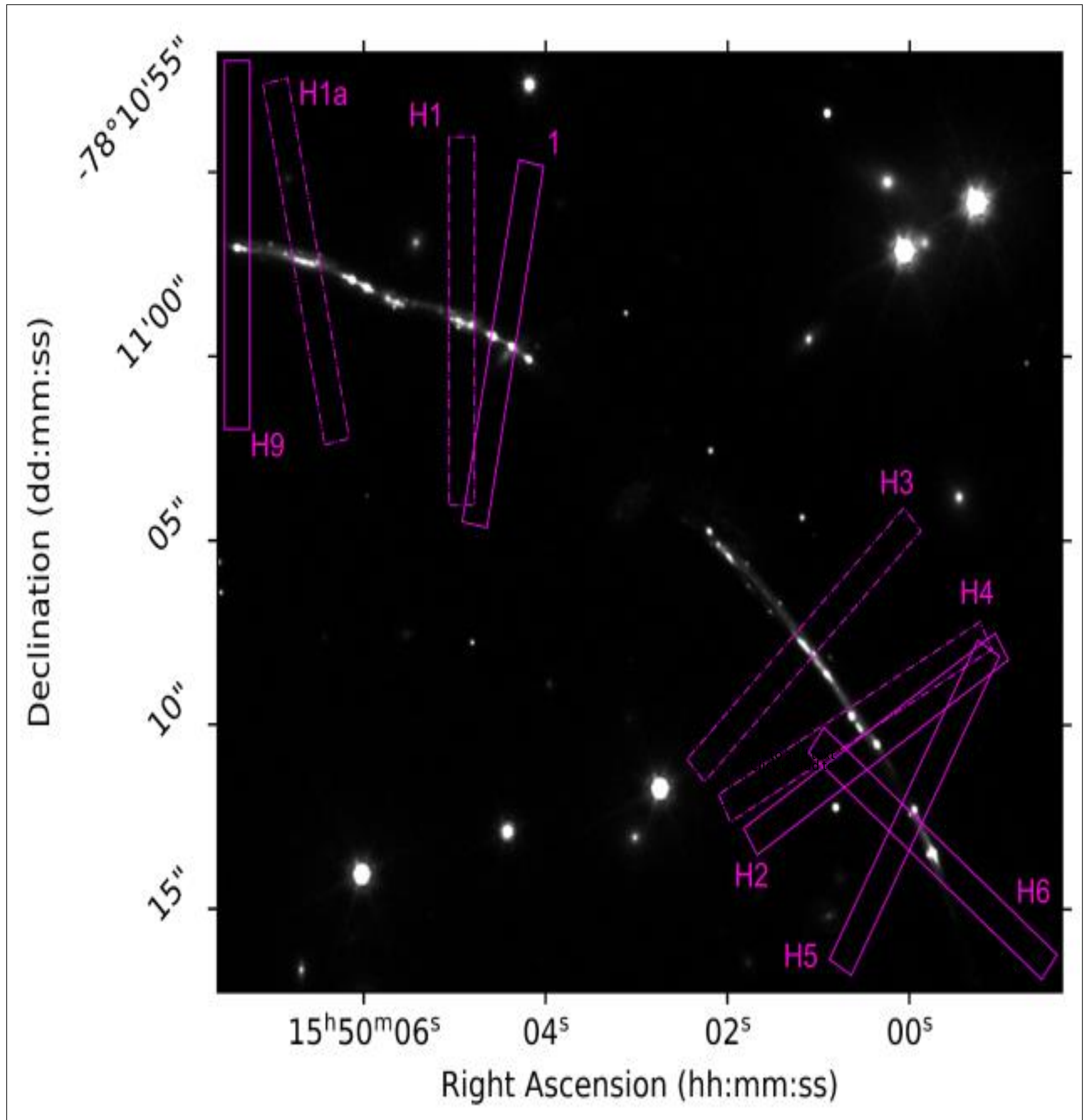

Figure 1: An image of the two largest, brightest arcs of the Sunburst Arc. Boxed and labeled in purple are the positions on the sky we observed. Solid boxes are locations known to leak ionizing radiation while dashed boxes do not.

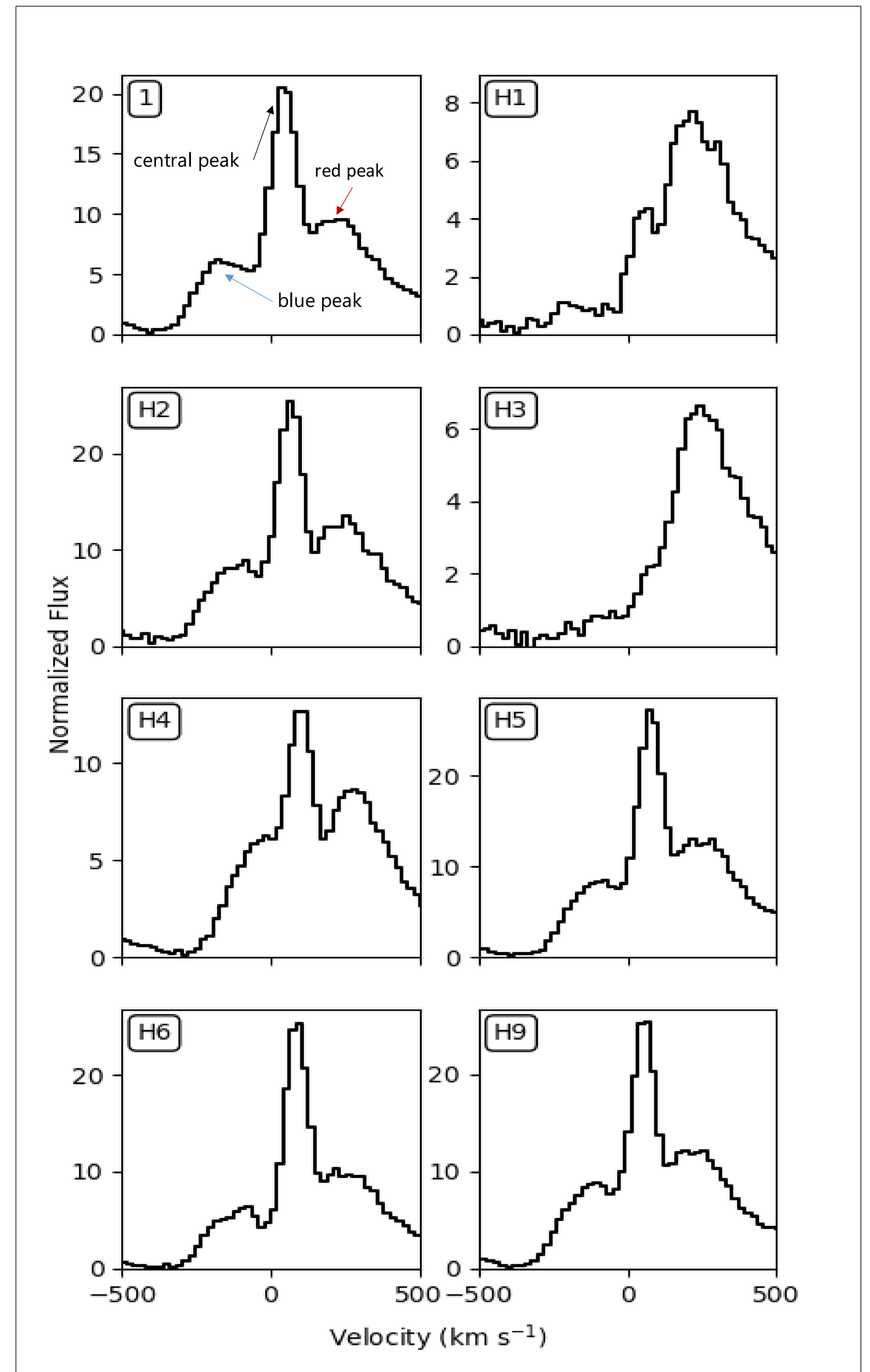

Figure 2: Lyα observations at different locations on the Sunburst Arc (the boxed areas shown in Fig. 1). Those with 3 peaks are known to leak more ionizing radiation, so this could lead to suggestions of how it escapes the galaxy based upon Lyα physics.

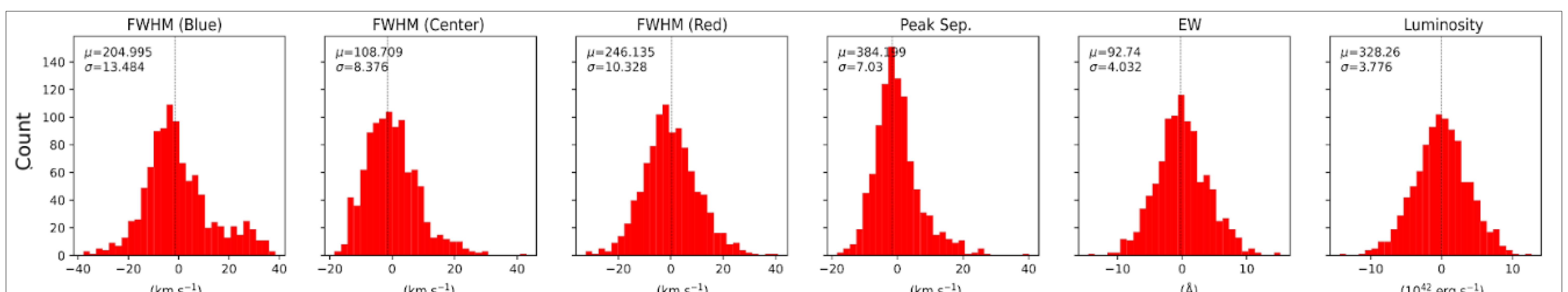

Figure 3: Due to the strong magnification, we can make measurements of the Lyα feature such as its relative strength (EW), broadness of each peak (FWHM), and the width between the two outer peaks. To measure these and estimate errors, we repeat the measurement 1000 times and add random noise to the data. The mean and standard deviations of these distributions (shown for one observation above), are the value and error of a certain measurement.

Results

We observed the Sunburst Arc (Fig. 1), a galaxy magnified by a galaxy cluster and known to leak ionizing radiation. Many observations show a unique Lyα signature (see Fig. 2), which is a type of light emitted / absorbed by neutral hydrogen. The same neutral hydrogen interacts with the ionizing radiation escaping the galaxy. So, characterizing Lyα light from the galaxy can inform how the ionizing radiation escapes. We believe the primary escape mechanism is highly nonuniform 'holes' in the neutral hydrogen surrounding the galaxy, which the ionizing radiation passes through (Fig. 4).

To further build a picture of the galaxy's physical environment, we also made measurements tracking:

- the star formation rate,
- dust content / properties of the ionizing sources, and
- absorption of light by large outflows of matter.

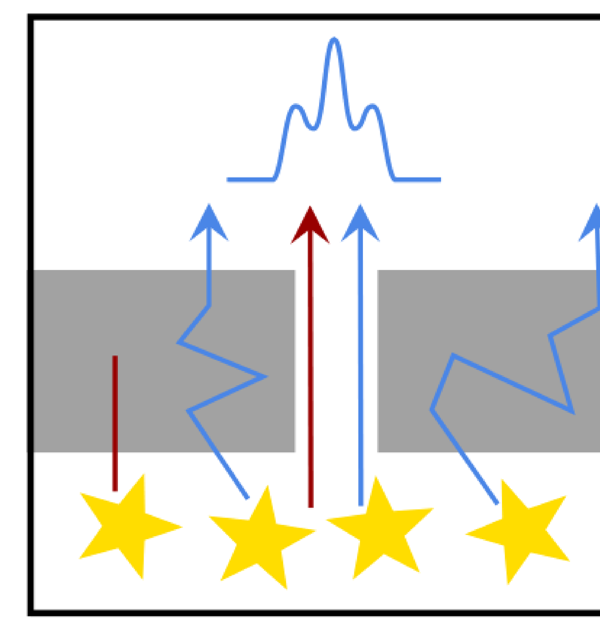

Figure 4: The triple peak forms when light escapes through 'holes' around the galaxy. If it interacts with the material, it becomes redder or bluer (side peaks).

Future

Though the Sunburst Arc is a much younger galaxy than those responsible for reionization, its strong ionizing radiation suggests it is a younger analogue to those older sources which contributed to reionization. Future research will focus upon the role of outflows and star formation, as well as the synergy between data from different telescopes.