The First Ionized Bubbles in the Cosmic Dawn

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A Sketch of Cosmic History

- Big Bang: 13.8 billion years ago
- Cosmic microwave background
- Cosmic Dawn
- Dark Ages
- Now
Growth of Ionized Bubbles

Simulation by M. Alvarez, R. Kaehler, and T. Abel
Lyman Alpha

• A particular wavelength of light, produced by young galaxies.
• Before reionization – it is scattered, like headlights in fog.
• After reionization– we can see it clearly now.

*By looking for Lyman alpha from galaxies we can determine if their surroundings are neutral or ionized.*
We undertook sensitive infrared imaging from the Kitt Peak National Observatory’s 4m Mayall Telescope + NEWFIRM camera.

We looked for Lyman alpha light from galaxies in the epoch of cosmic dawn.

We took spectra of DAWN survey galaxies with the Keck telescope on Maunakea, Hawai`i.
The Group EGS77 in the Cosmic DAWN Survey
## Galaxy Group EGS77

<table>
<thead>
<tr>
<th>Bluer light – galaxies not detected</th>
<th>Lyman alpha light - bright</th>
<th>Redder starlight – detected but faint</th>
</tr>
</thead>
<tbody>
<tr>
<td>F606W</td>
<td>F814W</td>
<td>NB</td>
</tr>
<tr>
<td>z8_SM</td>
<td>z8_4</td>
<td>z8_5</td>
</tr>
</tbody>
</table>

- **Galaxy Group EGS77**
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![Image](image.jpg)
Galaxy Group EGS77 in Cosmic History
Summary

• Reionization was the last time that anything interesting happened to a typical atom, and we want to understand its history.

• We have found an ionized bubble, traced by the earliest known galaxy group (EGS77), when the universe was 5% of its current age.

• This sheds new light on Cosmic Dawn.

• There is a bright future for studying EGS77 with JWST, and finding more like it with WFIRST.

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The Cosmic DAWN Survey Team

These results are described in more detail in a manuscript submitted to The Astrophysical Journal Letters and led by V. Tilvi.

The DAWN team consists of