MUSE integral-field spectroscopy towards the Frontier Fields Cluster Abell S1063

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In collaboration with:

MUSE

- Multi Unit Spectroscopic Explorer (MUSE)
- Recently installed at VLT
- 24 Integral Field Units (IFUs)
- 4800-9300 Å (1.25 Å/px)
- 1’x1’ FOV (0.2”/px)
Abell S1063

- Merging cluster
- $z=0.348$
- $\sigma \approx 1500$ km/s
Observations

- Science Verification
- June 25th & 29th
- PIs: K. Caputi & C. Grillo / B. Clement
- 3.1 hours total exposure time
- Standard pipeline reduction
- 3D datacube
MUSE data

AS1063 by MUSE
Cluster members

Emission spectrum with marked lines and wavelengths for various elements. The spectrum is shown in both emitted and observed wavelength scales. The red line represents the emission flux, with peaks at specific wavelengths corresponding to transitions in various ionized species.

$z: 0.335$

$z: 0.336$

AS1063 by MUSE
Cluster members

AS1063 by MUSE
High-z galaxies
Lyman-\(\alpha\) Emitters

\[ z = 6.107 \quad z = 4.113 \]

\[ z = 3.116 \quad z = 3.117 \]
Lyα- profiles

- 5 LAEs
- $z=3.116; 3.117$ (new!); $3.228$ (new!); $4.113$ (new!); $6.107$
- Narrow, FWHM=2.5Å
- Asymmetrical
- Double peaked with small separation
Presence of AGN

- Multiply lensed LAE at $z=3.116$
- UV emission lines
- C IV, He II, O III], and C III]
New $z=4$ LAE

Figure provided by Dan Coe
Conclusions

- MUSE is ideal for observing clusters
- 53 redshifts determined with 3.1 h exposure
  - 34 cluster members, 29 new
  - 17 galaxies at higher z, 10 new
- Possible AGN found
- New z=4 LAE found, consistent with models
- Wide range of science
### Emission lines

<table>
<thead>
<tr>
<th>Line</th>
<th>λ</th>
<th>low-z</th>
<th>high-z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hα</td>
<td>6562.8</td>
<td>-</td>
<td>0.42</td>
</tr>
<tr>
<td>[O III]</td>
<td>5006.8</td>
<td>-</td>
<td>0.86</td>
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<tr>
<td>Hβ</td>
<td>4861.3</td>
<td>-</td>
<td>0.91</td>
</tr>
<tr>
<td>[O II]</td>
<td>3726.3729</td>
<td>0.29</td>
<td>1.50</td>
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<tr>
<td>C III]</td>
<td>1907, 1909</td>
<td>1.52</td>
<td>3.88</td>
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<tr>
<td>C IV</td>
<td>1548, 1551</td>
<td>2.10</td>
<td>5.00</td>
</tr>
<tr>
<td>Lyα</td>
<td>1215.7</td>
<td>2.94</td>
<td>6.65</td>
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</table>
Velocity maps

AS1063 by MUSE
# Line ratio’s

<table>
<thead>
<tr>
<th></th>
<th>Measured</th>
<th>AGN(^1)</th>
<th>Hot O-stars(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C IV</td>
<td>17.3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>He II/C IV</td>
<td>0.20</td>
<td>0.10-1.51</td>
<td>0.03</td>
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<tr>
<td>O III]/C IV</td>
<td>0.25</td>
<td>0.59-0.71</td>
<td>0.24</td>
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<tr>
<td>C III]/C IV</td>
<td>0.29</td>
<td>0.49-0.57</td>
<td>0.29</td>
</tr>
</tbody>
</table>

\(^1\)Binette et al. 2003, A&A, 405, 975
AS1063 by MUSE
Fig. 1. Thumbnails showing the central region of the cluster AS1063 at 3.6, 24, 70, 100, 160, 250, 350, 500, and 870 $\mu$m (from left to right and from top to bottom). The contours correspond to the 870 $\mu$m emission detected with LABOCA at 3, 4, 5 and 6- ($\sigma = 1.1$ mJy). The Herschel drop-out source can be seen around the BCG (marked by the green cross) at the center of the 870 $\mu$m map. The arrows in the 100 $\mu$m map point at two low-z sources ($z = 0.3$ and 0.6), whose 870 $\mu$m emission is blended with the southwestern part of the high-z source.

Fig. 2. Left: residuals of the 870 $\mu$m emission after subtracting the two low-z sources. The cyan contours represent the $z = 6$ source model lensed by the cluster and observed at the resolution of LABOCA. The four images formed are labeled L1, L2, L3, and L4. The contour levels are at 0.25, 0.5 and $0.75 \times S_{L1}$, where $S_{L1}$ is the peak flux of the L1 image. The critical lines for $z = 6$ are overlaid in red. Right: HST color image of the cluster center of AS1063 assembled from images in the filters F606W (blue), F775W (green) and F125W (red). The white squares show the positions of the 4 images of a $z = 6$ background source. The thumbnails at the right are 300 $\times$ 300 zooms into these 4 images. The green contours show the 870 $\mu$m emission at 2.6, 3.9, 5.2, and 6.5 mJy (RMS $= 1.1$ mJy). The dotted green circle represents the LABOCA beam (FWHM = 24.3 $\alpha_0$).

Figure 1 from Boone+ 2013
LABOCA excess

Fig. 1. Thumbnails showing the central region of the cluster AS1063 at 3.6, 24, 70, 100, 160, 250, 350, 500, and 870 µm (from left to right and from top to bottom). The contours correspond to the 870 µm emission detected with LABOCA at 3, 4, 5 and 6 (RMS = 1.1 mJy). The Herschel drop-out source can be seen around the BCG (marked by the green cross) at the center of the 870 µm map. The arrows in the 100 µm map point at two low-z sources (z = 0.3 and 0.6), whose 870 µm emission is blended with the southwestern part of the high-z source.

Fig. 2. Left: residuals of the 870 µm emission after subtracting the two low-z sources. The cyan contours represent the z = 6 source model lensed by the cluster and observed at the resolution of LABOCA. The four images formed are labeled L1, L2, L3, and L4. The contour levels are at 0.25, 0.5 and 0.75 × SL1, where SL1 is the peak flux of the L1 image. The critical lines for z = 6 are overlaid in red. Right: HST color image of the cluster center of AS1063 assembled from images in the filters F606W (blue), F775W (green) and F125W (red). The white squares show the positions of the 4 images of a z = 6.1 background source. The thumbnails at the right are 300 × 300 zooms into these 4 images. The green contours show the 870 µm emission at 2.6, 3.9, 5.2, and 6.5 mJy (RMS = 1.1 mJy). The dotted green circle represents the LABOCA beam (FWHM = 24.3 arcsec).
LABOCA counterparts?
Photo-z estimates
MUSE

- **Wide Field Mode:**
  - $1 \times 1 \text{arcmin}^2$ FOV
  - 0.2” per spaxel

- **Wavelength:**
  - 4800 - 9300 Å
  - 1.25 Å per spaxel

- **Spatial accuracy** $\sim 0.12$”