arXiv:1705. 03479

ALMA PIN-POINTS A STRONG OVER-DENSITY OF U/LIRGS IN THE MASSIVE CLUSTER XCS J2215 AT $Z = 1.46$

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Draft version May 11, 2017

ABSTRACT

We have surveyed the core regions of the $z = 1.46$ cluster XCS J2215.9−1738 with the Atacama Large Millimeter Array (ALMA). We obtained high spatial resolution observations with ALMA of the 1.2 mm dust continuum and molecular gas emission in the central regions of the cluster. These observations detect 14 significant millimetre sources in a region with a projected diameter of just ~ 500 kpc ($\sim 1'$). For six of these galaxies we also obtain ^{12}CO(2–1) and ^{12}CO(5–4) line detections confirming them as cluster members and a further two millimetre galaxies have archival spectroscopic redshifts which also place them in the cluster. An additional ~ 4 millimetre galaxies have photometric redshifts consistent with cluster membership, suggesting that the bulk ($\geq 12/14$, $\sim 85\%$) of the submillimetre sources in the field are in fact luminous infrared galaxies lying within this young cluster. We then use our sensitive new observations to constrain the dust-obscured star formation activity and cold molecular gas within this well-studied example of a $z \sim 1.5$ cluster. We find evidence that the cooler dust and gas components of these galaxies may have been influenced by their environment reducing the gas reservoir for their subsequent star formation. We conclude that these actively star-forming galaxies have the dynamical masses and stellar population ages expected for the progenitors of massive, early-type galaxies in local clusters.

Keywords: Galaxies: clusters: individual: (XMMXCS J2215.9−1738) – galaxies: evolution – galaxies: formation

- Цель: по наблюдениям далекого скопления с высоким разрешением ALMA посмотреть, как формируются массивные галактики в центральной области.
- Spitzer found increasing numbers of starbursts in clusters out to z ~0.5-1, although these clusters still typically contained a core of passive galaxies.
- It is possible that the formation of galaxies might potentially result in a reversal of the star-formation - density relation in overdense regions at z > 1 (e.g. Tran et al. 2010).
- Данные противоречивы: сложности в отождествлении источников

To make progress on these issues we have obtained high-spatial resolution millimetre imaging of one of the well-studied high-redshift cluster which appears to exhibit a very significant over-density of submillimetre sources in its core: XCS J2215.9-1738. (z=1.46).

- We obtained high spatial resolution observations with ALMA of the 1.2mm dust continuum and molecular gas emission in the central regions of the cluster. These observations detect 14 signicant millimetre sources in a region with a projected diameter of just 500 kpc (~1’).

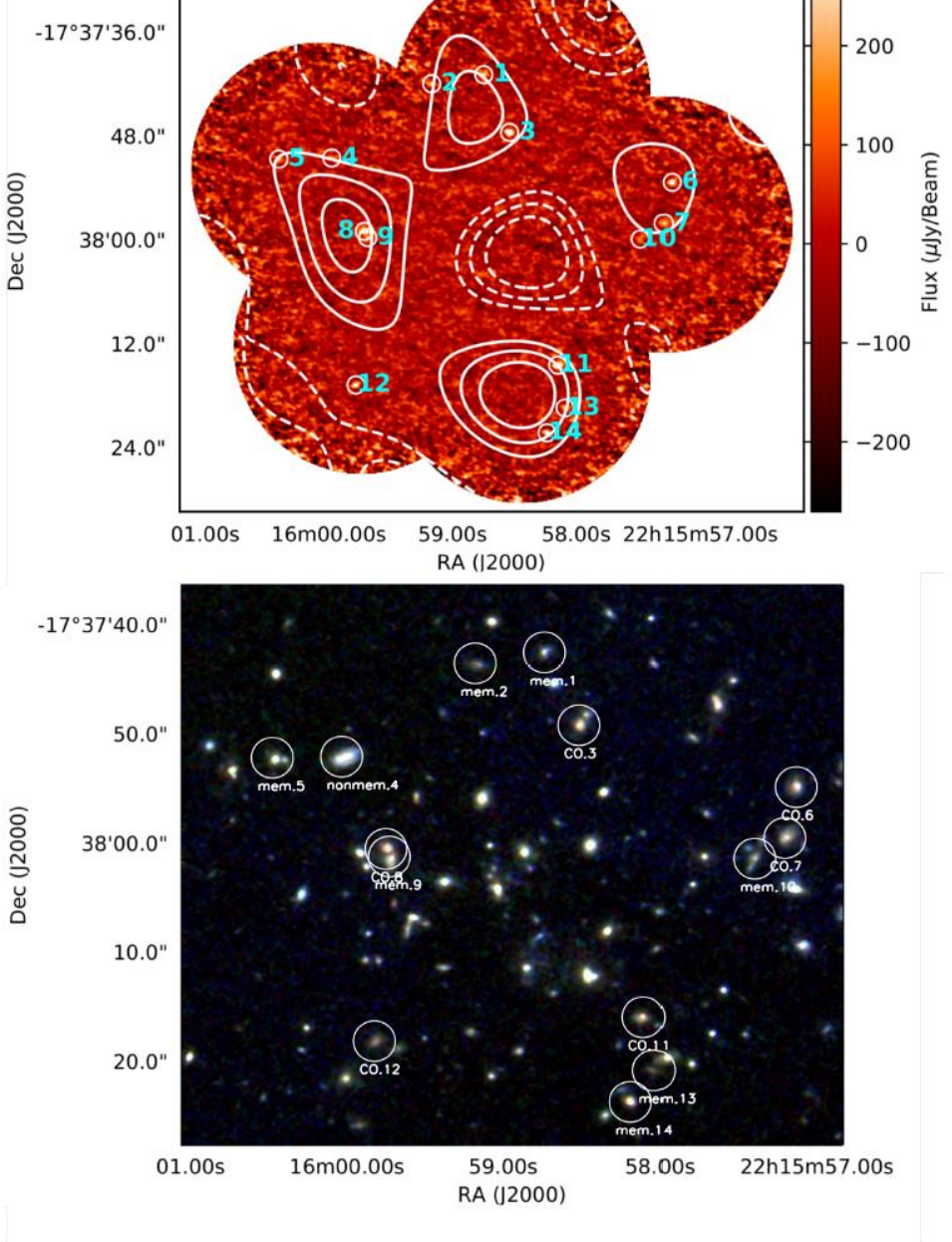


Figure 1. *Upper panel*: The ALMA 1.25 mm (Band 6) mosaic of XCS J2215 taken from six overlapping pointings covering a 500-kpc diameter region in the cluster core. We detect 14 $>4\sigma$ continuum detections, demonstrating a very significant overdensity of millimetre sources in this region. We list their properties in Table 1. We also overlay the SCUBA-2 850 μm SNR contours from Ma15 starting at 2σ and increasing in steps of 1σ (dashed lines showing the equivalent negative contours). *Lower panel*: Three colour *HST* image (F125W, F140W and F160W), with our ALMA detections labelled, showing the restframe V-band morphologies of the millimetre sources. We highlight source #4 as "nonmem" as this is a known interloper from its spectroscopic redshift and not considered a member of the cluster, all the other sources have ^{12}CO (labelled "CO") or archival optical spectroscopy or photometric redshifts (labelled "mem") which either confirm (eight sources) or suggest probable membership (five sources) respectively.

- Обнаружено 14 источников dust-continuum? Из них в 6 – излучение в молекулярных линиях СОю

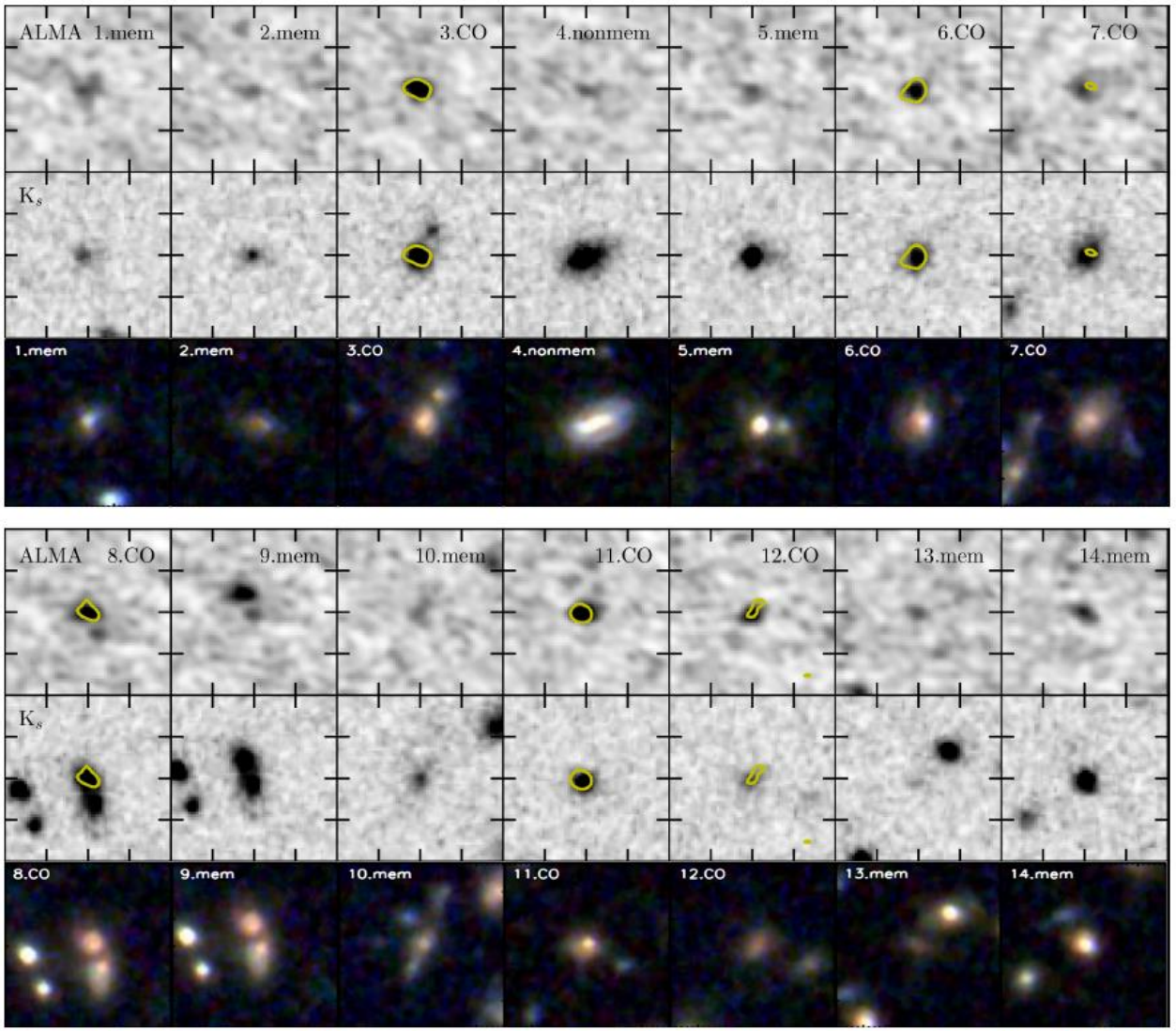


Figure 2. Thumbnails showing the ALMA Band 6 continuum (top row of each panel), K_s (middle row of each panel) and three-colour *HST* WFC3 images (1.25, 1.40 and 1.60 μm, lower row of each panel) of the SNR > 4 millimetre continuum sources detected in our map. Several sources display disturbed morphologies or very close neighbours (although these are typically faint in K_s and hence likely to be low mass), suggesting that dynamical interactions may be triggering the strong star formation in these galaxies. Each of these is centred on the positions given in Table 1. Six of the brightest sources in the ALMA continuum map: IDs 3, 6, 7, 8, 11, 12 additionally yield ^{12}CO(2–1) and ^{12}CO(5–4) emission line detections, confirming that these are members of the cluster. Each thumbnail is 6″ × 6″with major ticks every

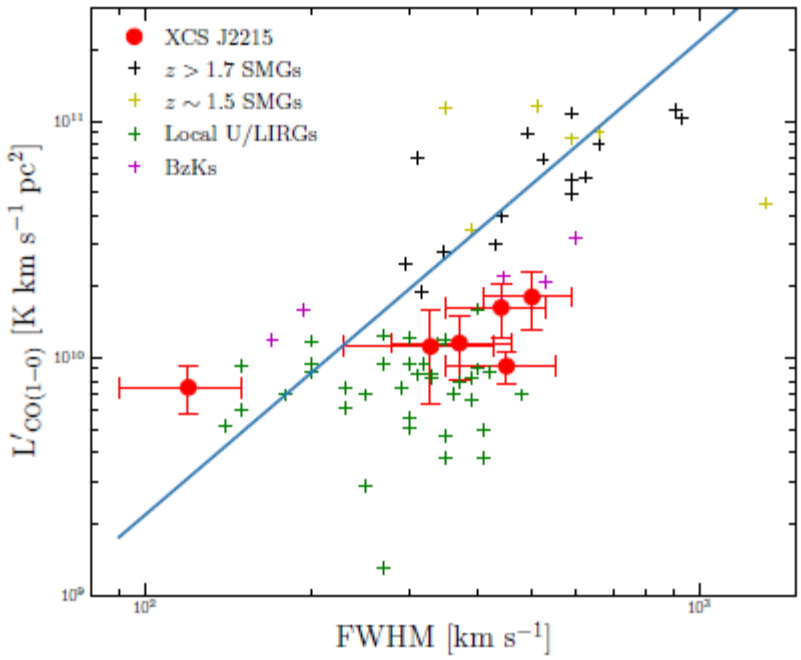
Размер каждого фрейма – 6”х6”

- We estimate the star formation rate
- from the far-infrared luminosities using the Kennicutt (1998) relation and assuming a Chabrier IMF. The derived luminosities of LIR $=10^{11}$-101^{2} Ls classify these cluster galaxies as luminous infrared galaxies (LIRGs).
- Our high resolution continuum observations with

ALMA have confirmed and significantly expanded the over-density of luminous, dusty star-forming galaxies.

- The median gas fraction is relatively low at fgas =0.3. Combining these gas masses with the star-formation rates, we estimate a median gas consumption timescale of 200pm100 Myrs.
- These star formation events may form

a signicant fraction of the stellar mass of these systems, up to 10^{11}Ms.


XCS J2215
$z > 1.7$ SMGs
$z \sim 1.5$ SMGs
Local U/LIRGs
BzKs
$L'_{CO(1-0)}$ [K km s^{-1} pc^2]
FWHM [km s^{-1}]
10^{11}
10^{10}
10^{9}
10^{2}
10^{3}

Выводы

- В ядре скопления идет активное звездообразование > 1000Ms yr^{-1}. It reflects a real reversal of the star-formation-density relation seen in the local Universe.
- Combining our precise ALMA positions with high-resolution HST imaging, we see a high fraction of millimetre continuum-selected galaxies with close companions on < 2-3'' scales, suggesting that galaxy-galaxy interactions may be a trigger for their activity.
- The time-scale ~200 Myrs is comparable to the time for a galaxy to cross the cluster core and so we anticipate that most of these galaxies will deplete their reservoirs before they exit the region they are currently seen in.
- Finally, we have demonstrated that these galaxies have some of the properties of the expected progenitors of the massive, early-type galaxies which dominate the high-density regions of rich clusters of galaxies at the present day.