Brightest Cluster Galaxies in Cool Core Clusters

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Motivation

The cores of a significant fraction of all X-ray luminous clusters have X-ray emission in their cores that implies cooling times of less than $10^9$ years.

The implied rates of cooled gas deposition are $1-300\, M_\odot \, yr^{-1}$ in that central region.
Where’s the beef?

The crucial issue with the prediction of significant gas cooling is to find where it goes.

The discovery of CO in a significant number of cluster cores (now more than 40) points to $10^9$-$10^{11.5}M_\odot$ in molecular gas.
DeMessieres et al. 2009

Egami et al. 2006

Normalized flux density, offset

DeMessieres et al. 2009
Our OTKP strategy

The key objectives of our OTKP is to obtain the line fluxes and velocity widths of as many as 6 atomic cooling lines (CII, OI, NII, OIII, NIII and SiI) with PACS and to obtain 70 to 500μm photometry with PACS and SPIRE for 11 brightest cluster galaxies.
Herschel SDP observations

For the SDP observations we selected three objects with a range of optical line flux, $L_{\text{IR}}$ and radio power - Zw3146 (z=0.29), A1068 (z=0.13) and A2597 (z=0.08).

We obtained spectra for CII (157\,$\mu$m) and OI (63\,$\mu$m) to test how bright these lines are.
The results

The spectra are of excellent quality and the lines are detected in two of the observations.
A1068 (z = 0.1386)

Continuum = 0.627 Jy

Peak = 1.999 Jy

FWMH = 0.227 \mu m
(~ 379 \text{ km/s})
A1068 ($z = 0.1386$)

Continuum = 1.600 Jy

OI 63 $\mu$m

Peak = 1.055 Jy

FWHM = 0.077 $\mu$m

($\sim 321$ km/s)
A2597 (z = 0.083)

Continuum = 0.261 Jy

CII 157 $\mu$m

Peak = 1.032 Jy

FWHM = 0.281 $\mu$m

($\sim$ 495 km/s)
A2597 ($z = 0.083$)

Continuum = 0.741 Jy

Peak = 0.858 Jy

FWHM = 0.135 $\mu$m ($\sim 592$ km/s)
The results

The spectra are of excellent quality and the lines are detected in two of the observations.

The photometry was equally successful and each BCG is detected at all 6 wavelengths covered.
A2597 SPIRE image 500/350/350μm
A1068 SPIRE image 500/350/350μm
Zw3146 SPIRE image 500/350/350μm
What does it all mean?

The spectra imply that the BCGs have the same CII line emission with respect to $L^\text{IR}_R$ as other galaxies and ULIRGs. The ratio of CII and OI are also consistent with other star-forming galaxies.

But the line widths are broader than expected from CO.
From Maiolino et al. 2005 \( \log \frac{L_{\text{CII}}}{L_{\text{FIR}}} \)
From Luhman et al. 2003
What does it all mean? II

The photometry are consistent with the expected dust temperature of $\sim 40\,\text{K}$ and $L_\text{IR}$ of $10^{10-12}L_\odot$.

The other cluster OTKP$s$ will detect many more BCG$s$ (see previous talks by Egami and Smith).
A1068 SED
SED for A2597

![Graph showing the Spectral Energy Distribution (SED) for A2597. The x-axis represents wavelength in micrometers, and the y-axis represents flux density in mJy. The graph includes various symbols and markers indicating different data points.]
What next?

The start of Routine Phase observations means that we will roll out observations of all our target lines and the other 8 objects. This will start with Centaurus, RXCJ1504-02, A1795 and A1835 in the next 2 weeks.
STOP PRESS!

I have been requested to mention some PV observations of a source that was found in May this year by Mark Swinbank (Durham) that offers a unique opportunity to make use of Herschel.

These data come with great thanks from we observers to the instrument and observatory teams.
Multi-wavelength serendipity

MACS J2135-0102: an X-ray luminous cluster at $z=0.32$ ... with a bright lensed LBG at $z=3.07$ and the brightest SMG, with $z=2.32$ and $S_{870\mu m}=106\pm3\text{mJy}$ (3x brighter than any other SMG)

$\phi=32.5\pm4.5$

(so intrinsic flux=3mJy; ie a typical high-z ULIRG).

For $\phi\approx 32$, 0.2"=100pc (source-plane)
To resolve the sub-mm emission, we used the Smithsonian Sub-mm Array (SMA) at 3 configurations: compact (1.5”), Extended (0.7”), Very Extended (VEX: 0.2”)
In all configurations, we detect the source and it continues to break up into smaller clumps
In highest configuration, beam is 0.2” (90-150pc after accounting for lensing).
Interpretation

SMA map overlayed with EVLA CO(1-0) map + SINFONI LGS AO

SMA 870\textmu m+434\textmu m contours (so - hot component is A+B)
Internal Properties

We can compare the sizes and luminosities of ‘clumps’ with those locally (MW, M31, M33 and LMC from IRAS).

- GMCs within SMMJ2135–0102 show a factor ~100x more (rest-frame) 250um luminosity at fixed size cf local GMCs.
- Increased star-formation efficiency? dust-to-gas ratios or dust properties? Top-Heavy IMF?

Swinbank et al. 2010 (Nature)