Deep ISOCAM Observations of Abell 2218

B. Altieri, L.Metcalfe, A. Biviano[1], K. Leech, K. Okumura & B. Schulz

ISO Science Operations Centre, Astrophysics Division, Space Science Dept. of ESA, Villafranca, P.O. Box 50727, Madrid, Spain

B. Mc Breen, M. Delaney

Department of Experimental Physics, University College, Dublin, Ireland

Abstract. We report on the mid-infrared imaging at 5, 7, 10 & 15 μm of the galaxy cluster Abell 2218 obtained with the ISOCAM instrument onboard ESA's Infrared Space Observatory (ISO), as part of an on-going program to image gravitational arcs and arclets in distant clusters. Several cluster galaxies as well as field galaxies are detected. We discuss their mid-IR flux properties.

1. Introduction

Abell 2218 is a very rich galaxy cluster (richness class 4, according to Abell et al. 1989), characterized by a large velocity dispersion of the galaxy population (σ_v = 1370 km/s, Le Borgne et al. 1992), and a high X-ray temperature and luminosity (T_x = 7.2 keV, see e.g. Markevitch 1997, $L_x = 2.9 \times 10^{44}$ erg/s[1] in the energy band 0.5–4.4 keV, see e.g. Kneib et al. 1996).

These properties, coupled to a relatively small distance ($<z>= 0.175$, Le Borgne et al. 1992), made this cluster an attractive target for studies of the Sunyaev-Zeldovich effect (Birkinshaw & Hughes 1994), and one of the closest clusters where gravitational arcs are detected. The amazing concentration of gravitational arcs and arclets has stimulated a huge observational effort first to get sub-arcsec imaging (from the ground, see, e.g. Kneib et al. 1995, and from space with HST, Kneib et al. 1996), and then to get spectra of the arcs (Ebbels et al. 1997).

The optical and near-IR observations have allowed a very detailed modelling of the mass distribution within the cluster (Kneib et al. 1996), confirmed later to a great level of accuracy, (Ebbels et al. 1997). It was found that the cluster mass distribution is bi-modal, with the main concentration centred on the cD galaxy. The X-ray surface brightness, as obtained via ROSAT observations, does not trace the gravitational potential as derived from the lensing analysis, a possible indication that the X-ray emitting gas is far from hydrostatic equilibrium (Kneib

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[1]Osservatorio Astronomico di Trieste, Italy

[1]In this paper we adopt $H_0 = 75$ km/s/Mpc and $q_0 = 1/2$

et al. 1996). This would also explain the discrepancy in the X-ray and lensing mass estimates (Markevitch 1997).

In this paper we report on the mid-IR observations of Abell 2218 done with ISOCAM on-board ESA's *Infrared Space Observatory* (ISO) satellite. The high sensitivity of ISOCAM allows us to determine the photometric properties of lensed and cluster galaxies in the mid-IR band, thus widening the wavelength coverage of their spectra. Mid-IR observations are critical in understanding the intrinsic nature of these distant galaxies, since a starburst is known to emit a large fraction of its energy in the mid-IR, due to dust grain re-processing of the emitted radiation.

2. Observations and data reductions

Abell 2218 was observed on March 3, 1996 and again on February 28, 1997 as part of an ISO program of observations of lensing galaxy clusters with arcs and arclets: Abell 370, Abell 2218, Cl2244-02 and MS2137-23. An important criterion for target selection was to choose the clusters with the brightest arcs in the optical, spatially extended and the farthest from the lens, due to the limited spatial resolution of ISO.
The observations were performed by rastering in microscanning mode yielding to very deep ISOCAM images of the galaxy cluster. The pixel field-of-view was $3''$ and the microscanning steps were $7''$ in both directions of the 5x5 raster. The cluster was imaged in the 4 filter bands, LW1 [4-5μm], LW2 [5-8.5μm], LW7 [8.5-11μm], and LW3 [12-18μm], at 5 or 10 sec integration times for a total observing time of 5.5 hours, covering a field of more than 2x2 arcminutes. The data reduction was done partly within the IDL based (ISO)CAM Interactive Analysis (CIA) package (Ott et al., 1997) and partly through the usage of C++ based Multi-resolution Median Transform (*wavelet*) techniques (Starck J.-L. et al, 1997). Cross-correlation of the two methods allows us to increase the reliability of source detection.

3. Results and discussion

The LW1, LW2 and LW3 maps are presented in figures 1 & 2a, as overlays on top of the HST image (courtesy J.-P. Kneib) of Abell 2218.

In the cluster core, no arclet is detected at a significant level at any wavelength in the mid-IR. This non-detection of arcs or arclets contrasts with our recent mid-IR imaging of Abell 370 (Metcalfe et al. 1997), where the A0 giant arc is clearly detected as the main feature and emitter in the cluster core at 15μm. But this giant arc is already a prominent feature in the optical, (first giant arc discovered), whereas arcs and arclets are fainter in Abell 2218.
The cD galaxy which is apparently centred on the cluster potential is clearly detected in the LW1 & LW2 filter bands. At 4.5μm (rest-frame wavelength 3.8 μm) the cD emission is extended, covering part of the optical halo; at 7μm the emission is much more confined to the centre, but with an extension along the optical major axis, probably contaminated by the neighbouring merging dwarf galaxies. At 10μm and 15μm it lies just above the detection limit of ISOCAM and no statement can be made on its extension. The mid-IR spectral energy

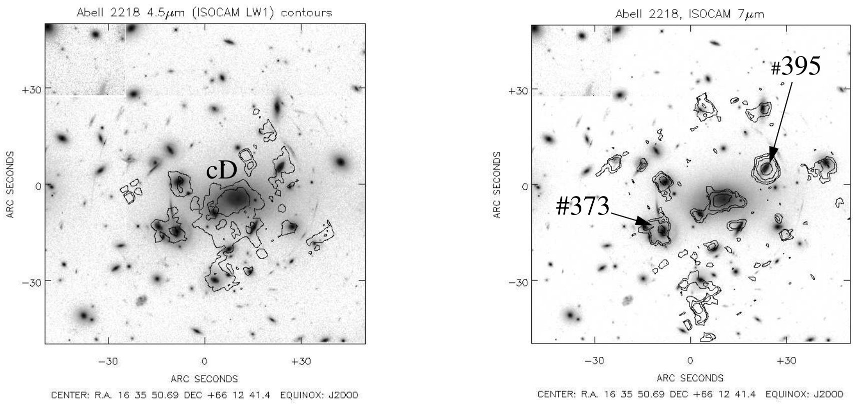

Figure 1. Abell 2218 4.5μm (a) & 7μm (b) contour maps

distribution up to 15μm seems to follow a simple Rayleigh-Jeans tail of the cold stellar component as found in optically-selected normal early-type galaxies (E, S0, S0a) in the Virgo cluster (Boselli et al. 1998). But due to the contamination by close-by galaxies it is very difficult to estimate the 4.5μm flux of the cD. The brightest cluster member galaxies are also detected at 4.5 μm and 7 μm. At the redshift of the cluster the 4.5 μm emission is mostly coming again from cold stellar photospheres. The 7 μm (LW2 band) (rest-frame 5.7 μm) emission includes a small fraction of PAH emission but comes mainly again from the cold stellar photospheres. At 10 & 15 microns most of cluster members have vanished (ie. are below or very close to our detection limit), as expected for normal early-type galaxies (ellipticals) where there is only the Rayleigh-Jeans tail mid-IR emission from cold stellar photospheres, in dust & gas poor cluster core ellipticals.

Still one cluster member galaxy #373 (numbering system from Le Borgne et al. 1992 in the following) is detected at 15μm, but also at 4.5 μm and 7 μm, it has a 'cart-wheel' like aspect, from the ring surrounding it and is probably a big face-on spiral galaxy. The 4.5μm and 7μm emission comes mostly from the nucleus whereas the 15μm originates apparently from the 'ring' structure. It could be PAH and small hot grain emission enhanced by star formation in tidal shocks in the 'ring'.

Object #323 is detected at 15 μm. This object was suspected to be an arclet candidate in the first deep multi-filter ground-based imaging (Pello et al. 1992), since it appeared as a fine unresolved extended structure, together with another 32 arclets in total. It is classified as one of the 235 arclet candidates in the first HST observation of Abell 2218 (Kneib et al. 1996). However, as noted by Kneib et al., it was also suspected not to be a strongly lensed object when comparison is made with shear orientation. This was again confirmed by Ebbels et al. (1997), object #323 being very elongated but at an angle of 45 degrees from the shear direction. Identification of several absorption features in its spectrum reveal it to be a cluster member at a redshift of z=0.179, a spiral seen edge-on.

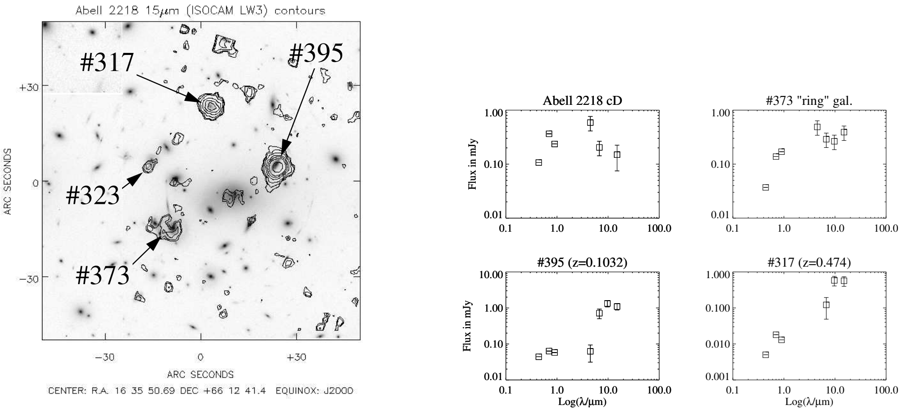

Figure 2. Abell 2218 15μm contour maps (a) and spectral energy distributions of 4 objects

To our surprise the brightest source by far from 7μm to 15μm is object #395, an apparently insignificant z=0.1032 (Le borgne 1992) foreground Sb galaxy, showing an ultraviolet excess and a strong Hα emission line, both indicating strong star formation of massive stars. Most of this mid-IR emission could then originate from the reprocessing by the small hot dust heated by a strong UV radiation field.

The second strongest emitter at long wavelength (from 10μm to 15μm), but much less at shorter wavelengths is object #317, a lensed galaxy at z=0.474 (Ebbels et al. 1997), a rather red object from the visible to the mid-IR. First indications show that this type of lensed object is common on our larger field imaging towards lensing clusters (Metcalfe et al. 1998 in preparation)

The spectral energy distributions from the visible (B,R,I) to the mid-IR of the 4 objects discussed above are shown in fig. 2b

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