ISOCAM OBSERVATIONS OF M31

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Abstract

We present ISOCAM images of the Andromeda galaxy center. They display an elliptical stellar bulge and a more complexe dust distribution. The spatial dust distribution follows a mini-spiral structure identical to the distribution of absorption in optical wavelengths. A discussion on the nature of the dust from CVF observations is also presented. The central part and the molecular ring of M31 are excellent targets for FIRST.

Key words: Galaxies: individual: M31 - Galaxies: ISM

1. Introduction

Star formation in the Andromeda galaxy M31 (Hubble type: Sb ; inclinaison = 77°; position angle = 38°; 1′= 200 pc) presents many differences from that in our Galaxy. M31 total star formation rate is only 1/10 of that in the Galaxy in spite of a higher total mass (Xu & Helou 1996) and the ratio of the far UV flux to the visible flux is quite smaller than in our Galaxy. The spatial distribution is also quite peculiar : star formation is only active in a ring of 10 kpc in radius, the molecular ring. The metallicity in M31 is roughly similar to that in our Galaxy.

From ISOPHOT observations (Haas et al. 1998), the far-IR luminosity of M31 is only 20% of that of our Galaxy. The bulk of the dust is cold with a temperature of 16K, mostly located in the molecular ring and in two central areas. Haas et al. (1998) has found a dust/gas ratio of 1/130 (1/170 in our Galaxy).

Mid-IR data from ISO give the best unbiased view of the distribution of dust in the bulge of M31. First, we will report conclusions on the dust properties from the CVF observations. Then we will present images from ISOCAM. After removal of the stellar bulge contribution, we will discuss the spatial dust distribution and its consequences.

2. Nature and properties of the dust

Spectral data have been obtained with a cicular variable filter (CVF mode) on ISOCAM (covered wavelength : 5.5 to 16.5 μm). For more details , see Cesarsky et al. 1998 and Pagani et al. 1999.

The spectrum of the central 3 arcminutes (as well as spectra in the molecular ring) is characterized by a strong broad band at 11.3 μm while other PAHs are absent or faint. Such spectra differ completely from usual interstellar dust spectra.

Neutral PAHs are known to emit strongly in the 3.3 and 11.3 μm bands but faintly in the 6.2 7.7 and 8.6 μm ones (Allamandola et al. 1999) and are possible candidates for M31 dust. However they also emit a strong band at 13.5 μm which is not seen in M31. However neutral PAHs do not absorb photons at wavelengths longer than 5000Å, and we do not understand how they could be excited so efficiently in M31 given its UV flux (5% or less of the local galactic value see Cesarsky et al. 1998).

SiC emits a band near 11.3 μm and might be a better candidate. SiC emission is seen in carbon rich AGB stars and SiC coming from such stars is present in meteorites, so that this material should exist in the interstellar medium. Unfortunately the position and the shape of the emission band when emitted transiently by nanometer size SiC grains are not known (Mutschke et al. 1999).

3. ISOCAM observations

The observations have been obtained with the 32 x 32 elements mid-infrared camera ISOCAM on board of the ISO satellite (see Cesarsky et al. 1996, for a complete description).

The central region was mapped in 4 broad filters : LW1 centered at 4.5 μm, LW2 at 6.75 μm, LW3 at 15 μm and LW6 at 7.7 μm. The emission in the LW1 filter is essentially due to the red giants of the bulge. LW6 includes the 7.7 μm PAHs emission and has a shorter bandwith than LW2.

For each filter, several 2.1 s exposures (around 12) have been taken at different positions on the sky so that it is possible to rebuilt a larger field image of the object (raster mode).

For the data reduction we used CIA software (Starck et al. 1999) . Some square patterns still remain at the end of reduction and this is partly due to the fact that the data reduction are not yet completely finalized.

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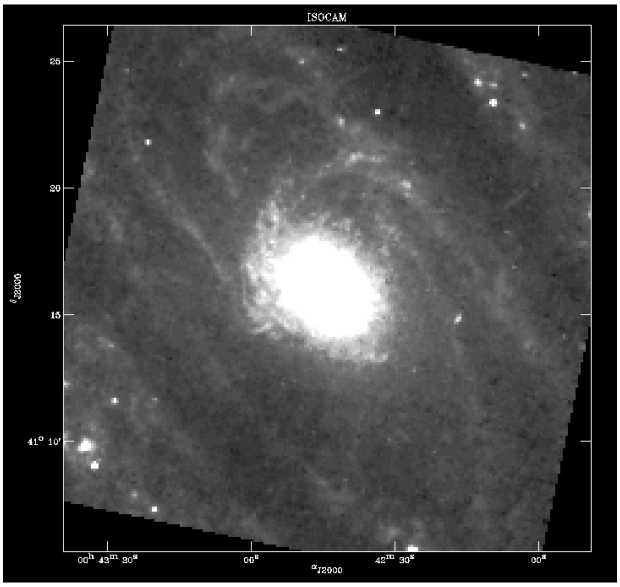

Figure 1. Image in LW6 of M31 central part. The elliptical contribution of the stellar bulge is clearly detected. The pixel size is 6″ and the total field is about 21′. Coordinates are J2000. From Willaime et al., in preparation.

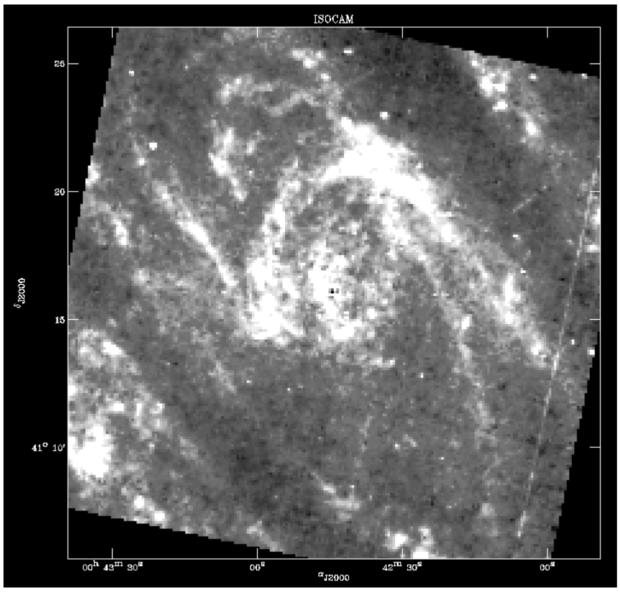

Figure 2. Result of the subtraction of the precedent figure with the bulge model (see text for details). The residual structures follow the spatial dust distribution. The nucleus location correspond to the black dot at the center of the image.

4. Spatial distribution of the dust

The LW1 image corresponds to the stellar emission from the bulge. It presents a very smooth regular elliptical shape that can be recognized also in the other filters (Fig. 1). Since the image is very noisy, we decided to build a bulge model by fitting ellipses to the LW1 isophotes. This model was assumed to represent the spatial distribution of the stellar emission in all the mid-infrared wavelengths (with only a change in flux scale).

After subtraction of the stellar bulge, the residuals in LW6 image show the distribution of insterstellar matter at 7.7 μm. It displays an excentered elliptical ring with a diameter of around 1.5 kpc. Moreover, it seems that a straight structure connects the location of the bulge center and the ring (Fig. 2). Two or three faint spiral arms seem to begin at two opposite side of the ring. All the structure resemble to a mini-spiral in the center of the galaxy. The emission at the image corners comes from the molecular ring at 10 kpc. All these structures are also present in LW2 and LW3 images.

5. Comparison with other observations

5.1. Optical extinction

The extinction maps are based either on visual examination of dark lanes projected against the bulge light (Hodge 1992) or on multicolor surface photometry (Melchior et al. 2000). In both cases, they are biased against detection of dust located on the far side of the bulge. However, Hodge (1992) underlined the fact that the absorbing clouds in the center of M31 form a small spiral. Direct comparison with the extinction map of Melchior et al. (2000) gives a qualitatively excellent correspondence (Fig.3).

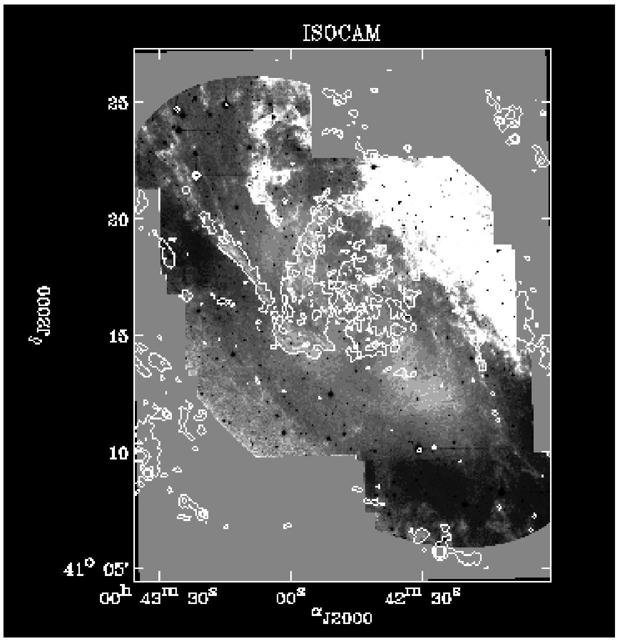

Figure 3. LW6 contours superimposed to the extinction map from Melchior et al. (2000)

5.2. Direct observations

The comparison with direct observations of the gas is quite difficult since there is little HI in the bulge and the existing CO data are sparse and not sensitive enough to display all the molecular emission (except in the observations of Melchior et al. 2000 but it concerns only few locations).

The brightest region in the ISOPHOT image (at 175 μm) is a supergiant cold molecular cloud with no sign of star formation (Schmidtobreick et al. 2000). It corresponds to a bright structure in LW6 located at the beginning of one of the "spiral arm" (Fig. 4).

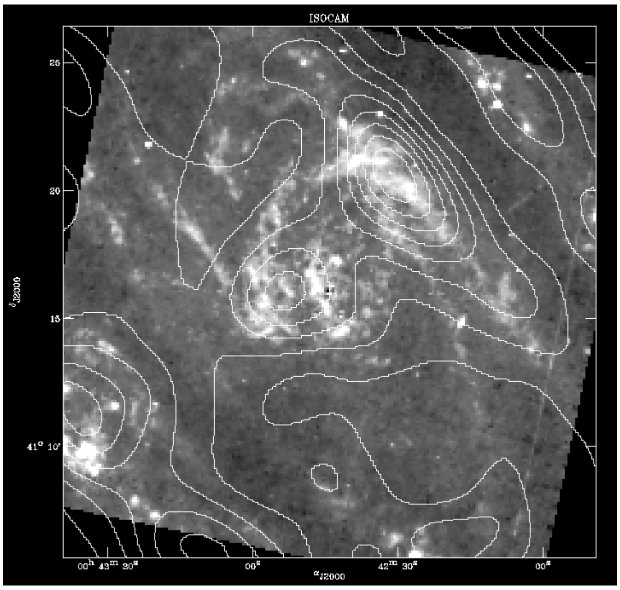

Figure 4. Contours of the emissiom at 175 μm superimposed to LW6 map in greyscale. The FIR image was taken through the C200-160 ISOPHOT filter and has an angular resolution of 1.3′ (Haas et al. 1998).

5.3. Kinematical data

Kinematical studies of the center have been made using radial velocities. Jacoby et al. 1985 interpreted their Hα observations as a bar + ring structure. Boulesteix et al. 1987 find an overall rotation pattern with low velocities (around 100 km/s). They concluded that most of the gas is rotating in a strongly tilted plane. The emission is very faint, but the structure observed in Hα corresponds roughly to what we see in the LW6 filter (size and orientation of the "ring", straight structure at the same location, etc.).

The CO radial velocities from Melchior et al. (2000) seem to correspond to the Hα velocities, suggesting that the molecular clouds lie in the same plane as the ionized gas.

6. Conclusion

Most of the dust in the Andromeda galaxy is located in the center and the 10 kpc molecular ring. It corresponds to the star formation regions in the molecular ring, the origin of dust in the center is more puzzling. But the presence of a mini-spiral in the center of M31 will have direct consequences in dynamical studies of the galaxy, and more precisely on the existence of a bar.

FIRST is the best instrument to perform a complete study of the interstellar matter in our nearest neighbour. For example, a [CII] survey of the center with HIFI should complement the Hα observations. Far-IR observations at higher resolution than with ISOPHOT will be of high interest.

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