LARGE-SCALE MAPS OF M31 AT MIDDLE AND FAR INFRARED WAVELENGTHS

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(on behalf of the IRAS science team)

The satellite IRAS (see Neugebauer et al. 1984; see also Gautier and Hauser, this volume) was in operation from January 27 until November 22, 1983. Its main goals were to carry out a survey of the sky at 12, 25, 60, and 100 micron and to make observations around selected positions achieving higher sensitivity or better angular resolution than provided in the survey. Among the very first targets of these pointed observations was the Andromeda galaxy, M31, because it was considered of prime importance and was about to leave the observing window. Here we report briefly on crude maps made from the first measurements. A more elaborate presentation may be found in Habing et al. (1984) and a publication of all the data on M31 is planned for the future.

We obtained two adjacent maps of 3 by 3 degrees each by making raster scans with the full set of 59 active detectors. Each detector has a width of approximately 5 arcmin and a height that depends on the wavelength band: from 0.8 arcmin at 12 micron to 3 arcmin at 100 micron. The scan direction practically coincided with the minor axis. Therefore the angular resolution of the maps is (almost) the same in the direction of the major axis, but in the direction of the minor axis it degrades progressively with wavelength. In Figure 1 we show a combination of three maps.

The following are the main conclusions drawn so far:

1. The total luminosity of M31 between 12 and 100 micron is $1.2 \times 10^9\ L_\odot$. This value has an uncertainty of at least a factor of two because of remaining uncertainties in the calibration and because of possible baseline effects. In addition M31 emits perhaps the same amount of radiation beyond 100 micron. We thus estimate that M31 emits at most $5 \times 10^9\ L_\odot$ of infrared radiation. Compared to the total bolometric luminosity of M31 it is seen that less than 10 percent of the stellar light is re-emitted in the infrared. This is a small percentage compared to what is found in most other spiral galaxies, especially those of later type (Sbc, Sc, Sd) (see de Jong et al., 1984; Soifer et al., 1984). It is unknown whether M31 is a poor emitter for its type, that of an Sb galaxy.

H. van Woerden et al. (eds.), The Milky Way Galaxy, 451–456.

https://doi.org/10.1017/S0074180900242939 Published online by Cambridge University Press

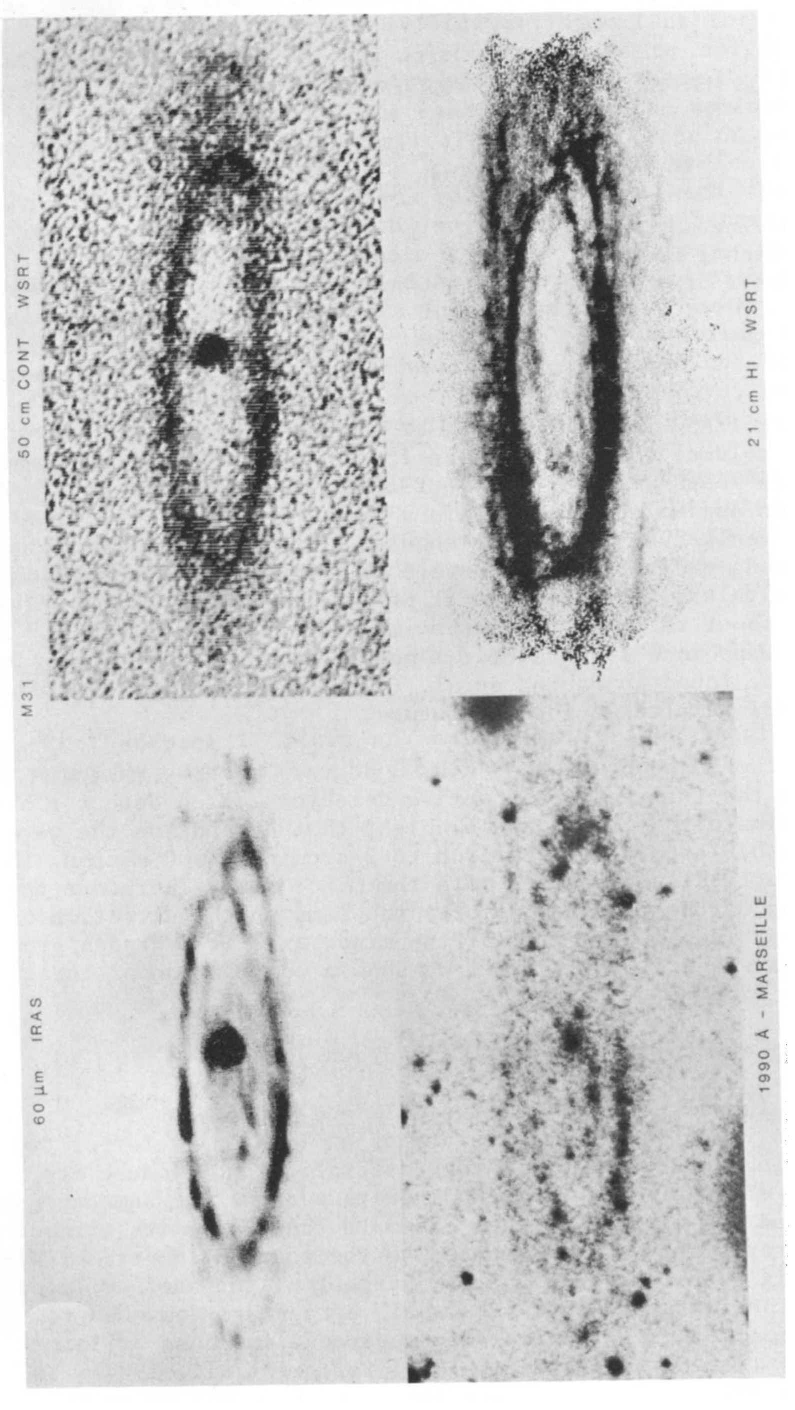

Figure 2. Comparison of the IRAS infrared emission from M31 with emission in the UV (Deharveng et al.) in the 50-cm radio continuum (Bystedt et al.), and in the 21-cm line (Brinks and Shane).

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2. At each of the four wavelengths the emission comes mostly from a ring of about 45 arcmin (major axis) diameter. This ring is also seen at several other wavelengths (see Figure 2) and it apparently represents the part of M31 that is actively forming new stars: the same ring can be seen in a UV map at 100 nanometer (Deharveng et al., 1980), in the 21cm line of HI (Unwin, 1980a, 1980b; Brinks and Shane, 1984) and in the non-thermal radio continuum at 50 cm (Bystedt, Brinks, de Bruyn, Israel, Schwering and Shane, in preparation). Also the CO emission is very probably concentrated in this ring (Boulanger et al., 1981). The distribution of HII regions in M31 as given by Pellet et al. (1978) closely resembles the distribution of the IR emission. The same is true for the 21cm line emission. On optical photographs the prominent dust lanes coincide very precisely with the IR emission in all four wavelength bands. These various coincidences convince us that the IR emission is indeed from dust heated by embedded, probably young stars. It is conceivable that the emission at the longest wavelength is, in part, originating from dust that is less intimately associated with the star-forming regions but that is part of the more diffuse interstellar medium. This seems to be the case in our Galaxy (e.g. Mezger et al., 1982) and could equally apply to M31, as far as our maps are concerned.

Although the ring is the most dominant feature in our maps, some IR emission is associated with dust lanes inside the ring and with a few HII regions outside of the ring on the major axis.

3. An unexpected feature of all maps is the emission from the central part of M31. The centre is quite prominent in the maps, but it contributes less than two percent to the total IR emission. Interstellar matter in the centre of M31 is only known in the form of dark clouds (Baade, 1963). An upper limit of 10^6 $M_{\odot}$ has been set for the total cloud mass by Gallagher and Hunter (1981). HI and CO emission has not yet been detected. The IR emission from the centre has a higher ratio of 60 to 100 micron flux density than that of the ring and the emitting dust at the centre will thus be somewhat hotter. The grain properties in the far IR are still rather uncertain, but adopting values recommended by Hildebrand (1983) we estimate that the dust has a temperature of 34K and a total mass of 3000 $M_{\odot}$. For a normal gas-to-dust ratio of 100 the total amount of interstellar matter is comparable to the value quoted above. The temperature of 34K is rather high, when compared with e.g. the grain temperature in the solar surroundings(see e.g. Mezger et al., 1982). Most certainly this can be attributed to the much stronger radiation field at wavelengths longward of 300 nanometer, produced by the large number of late-type giants in the bulge of M31. The ultraviolet radiation field there is comparable in energy density with that in the solar surroundings and thus insufficient to heat the grains.

4. We have detected IR emission from the two close companions, M32 and NGC 205. Both are elliptical galaxies but the nature of their IR emission is radically different. M32 is strongest at the shortest wave-

length, very weak at 25 micron and not at all detectable at the longest wavelengths. The amount of radiation is compatible with emission in the photospheres of late-type stars. NGC 205 is not detected at the shortest wavelengths, is weak at 60 micron and is a 2-Jansky source at 100 micron. NGC 205 is known to possess blue stars and star formation is probably taking place (see e.g. Deharveng et al., 1982). The character of the IR emission supports this conclusion.

ACKNOWLEDGEMENT. I thank Piet Schwering for massaging the M31 maps and producing the colour picture. The Infrared Astronomical Satellite IRAS was developed and has been operated by the Netherlands Agency for Aerospace Programs (NIVR), the U.S. National Aeronautics and Space Administration (NASA), and the U.K. Science and Engineering Research Council (SERC).

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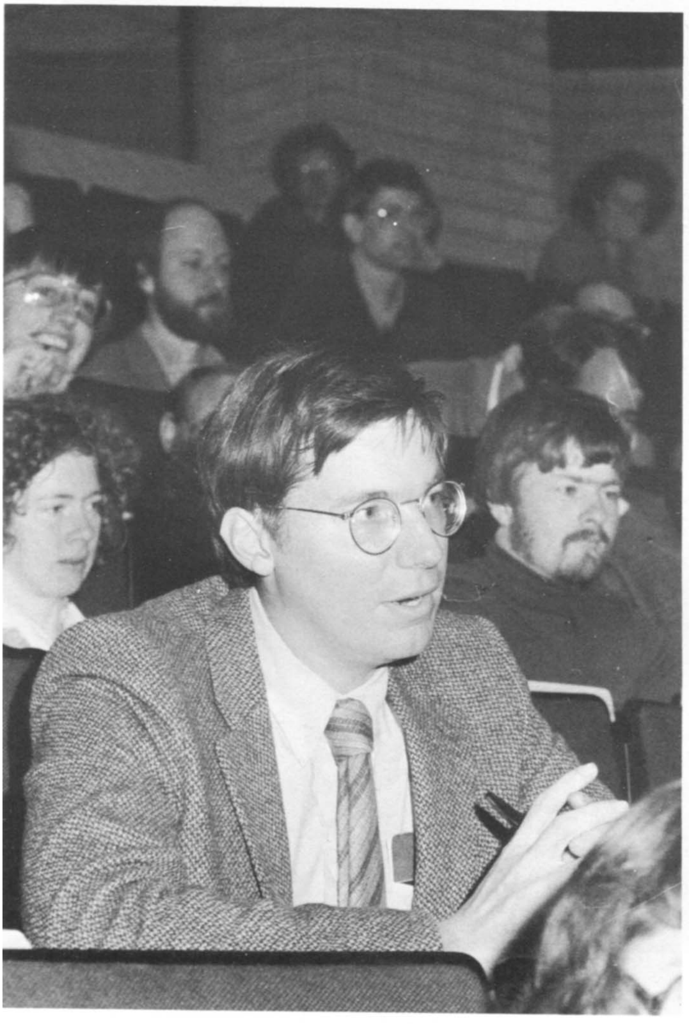
DISCUSSION

A.A. Stark: IRAS is, as you said, a sensitive detector of dust. There is a feature in the data, a line of dust that connects the nucleus of M31 to the ring of gas in the disk, in position angle roughly 90°. This feature also appears in Einstein X-ray and soft-UV maps of M31. It may be that this object is the projection of the major axis of the bar in M31. It is possible to fit the photometry (including the tilt in the isophotes of the bulge) with a triaxial model of the bulge of M31, where the (3-dimensional) major axis of the bulge projects onto that feature.



Stark, between Elaine Sadler and Reid, in discussion with Burton

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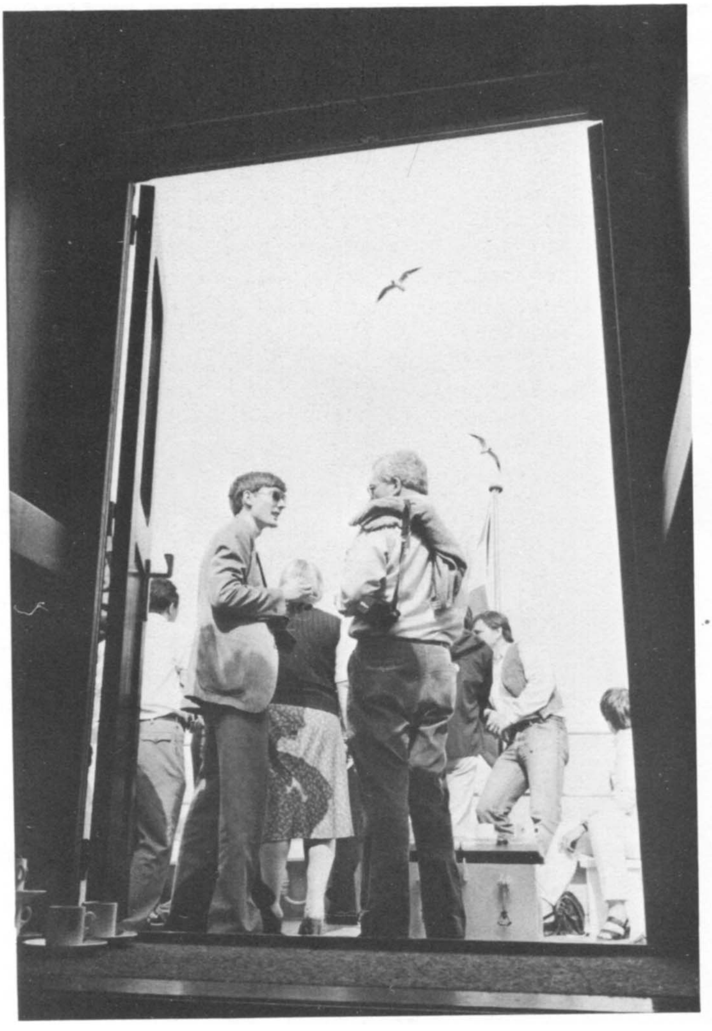
P.W. Hodge: Is the infrared flux for NGC 205 consistent with the optically-measured mass of dust?

Habing: I do not know. The flux is a twentieth of that received from the nucleus of M31; but the dust in NGC 205 is cooler, so its amount should be relatively greater.



Brinks (left) and Bash on the Frisian lakes. Background: Hu (left) and conference secretaries Joke Hunnink, Marijke van der Laan and Ineke Rouwé LZ

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