INTERSTELLAR MATTER IN ACTIVE GALAXIES

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In 1986 three papers [1,2,3] claimed that for bright IRAS galaxies their luminosity L is proportional to the amount of interstellar matter M_{gas} they contain. M_{gas} was derived from the CO luminosity [1,2] and from the submm/mm dust emission [3]. Both methods roughly agree and it is found that $L/M_{gas} \approx 5...10$ in solar units. However, detailed comparison is still far from satisfactory. For example, for the five objects detected in both samples [1] and [3] the dust emission gives (for comparable beams and using the same distances) on the average 2.5 larger gas masses than CO. This may be partially explained by the fact that the dust also emits from regions of neutral hydrogen, whereas CO emission is restricted to H_2 clouds. Nevertheless, gas mass are still controversial.

The bright IRAS galaxies were generally thought to be nonactive. We investigated whether active galaxies would follow a similar relation between L and M_{gas}. As our sample for active objects we chose Markarian galaxies because they were initially defined in a very simple way: they have a compact, blue core with emission lines. Later it was shown that many of the Markarians are star burst galaxies and Seyferts; quasars are not among them.

Up to now we have observed the dust continuum from 50 Markarians on the IRAM 30m-telescope at 1.3 mm with a 12" beam and 15 of them also at 0.87 mm [4,5]. We found that also for them $L \propto M_{gas}$, but $L/M_{gas} \approx 100$, instead of 5...10 for the nonactive galaxies. Furthermore, the coldest dust component in the Markarians has $T_d \approx 30$ K, instead of 15...20 K for the nonactive bright IRAS galaxies. This implies that, at least in a statistical sense, one may directly convert the 100 μm emission of the Markarians into gas masses, whereas for the nonactive galaxies most of the dust is cold and does not show up in the IRAS bands.

The continuum data are summarized in Fig. 1. It suggests that the ratio L/M_{gas} determines whether a galaxy is active or not. However, serious problems are connected with Fig. 1. We mention the following:

a) the measurements from which the luminosity and the gas mass are derived generally refer to different areas on the galaxy.
b) the relation L vs. M_{gas} may be artificial. It arises for a flux-limited sample because distant galaxies have to be strong in both L and

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M_{gas} and thus automatically appear in the upper right hand corner of Fig. 1.

c) the gas masses may be seriously wrong because the assumed conversion of 1.3 mm flux (or CO luminosity) into M_{gas} is faulty.

d) the difference in L/M_{gas} between active and nonactive galaxies maybe an observational artefact caused by the smaller beam employed in the measurements of the active galaxies. L/M_{gas} would be beam-size dependent if the luminosity is due to a compact source, which is surrounded by an extended region of interstellar matter.

To check the reliability of previous gas mass determinations (item c) we compared, using identical beams, M_{gas} derived from dust emission at 1.3 mm and from the CO(2-1) luminosity [6]. The conversion of optically thin mm-dust emission into gas mass is straightforward, but it contains the dust-to-gas ratio, where we used the galactic value, and the poorly known dust emissivity ε; fortunately, ε is not likely to change from one

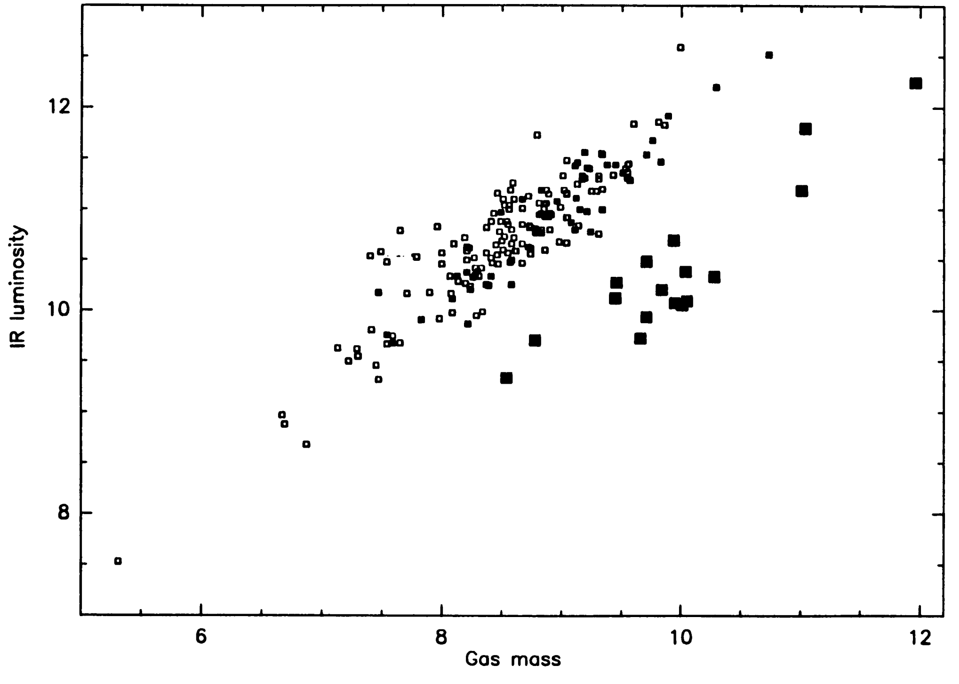

Figure 1. Logarithm of gas mass from 1.3 mm dust emission vs. log IR luminosity (> 10 μm) in solar units. (Nonactive) bright galaxies: big filled squares; (active) Markarians with 1.3 mm continuum data: small filled squares; Markarians with IRAS data only: small open squares. For the latter the 1.3 mm flux has been extrapolated from the IRAS bands.

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galaxy to another. How the CO luminosity coverts into M_{gas}, on the other hand, is not fully understood, particularly for extragalactic objects. Among other problems, a necessary assumption for this conversion, namely that the clouds are virialized, may not be fulfilled [7]. Nevertheless, the comparison between the two methods for obtaining M_{gas} gave agreement within a factor of three.

Item d) can be clarified by establishing the mm-size of the active galaxies. If their angular extent is not larger than the 12" beam used in the measurements of M_{gas} in Fig. 1 then the separation between active and nonactive galaxies in that figure should be real. To this we end performed continuum and CO measurements with SEST, which has twice the beam of the IRAM 30m. Preliminary results indicate [8] that the interstellar matter in the Markarian galaxies is, indeed, very concentrated to the center, thus corroborating Fig. 1.

Devereux and Young argued during this conference that there exists a very cold dust component in the active galaxies, which contains ≈ 90% of the total dust mass, but passes undetected even at 1.3 mm. Therefore, they say, our dust continuum measurements at 1.3 mm grossly underrate the total gas mass of the active galaxies. This proposition can be checked. Let us assume that 50% of the measured flux at 1.3 mm is due to this hypothetical very cold component. This implies that its temperature must be well below 10 K. A minimum heating source to all grains is the FIR radiation field peaking at ≈ 100 μm, which penetrates even the most opaque clouds. Consider as an example M82 ($L = 3\ 10^{10}\ L_\odot$; half-power size at 1.3 mm of 300 pc x 600 pc [9]) and silicates grains after Draine, which have at 100 μm an absorption efficiency $Q = 150a$ (radius a in cm). It is then easy to convince oneself that in the strong FIR field dust temperatures can under no circumstances drop below 20 K. This result can be scaled to the Markarians. At a mean distance of 60 Mpc our 12" beam has a radius on the galaxy of 1.8 kpc. As the Markarians are typically 10 times more luminous than M82 the ratio L/R^2 stays unchanged and one expects again minimum grain temperatures above 20 K.

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