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CENTRAL ACTIVITY IN 60 MICRON PEAKERS

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Abstract

We present CCD imaging results of our sample of IRAS galaxies with spectral energy distributions peaking at 60μm (Vader et al 1988). The results support our suggestion that the activity in 60μm peaking galaxies is centrally concentrated, and represents an early stage of dust-embedded nuclear activity. This activity is probably triggered by a recent interaction/merger event as indicated by their peculiar optical morphologies. We propose that 60μm peakers are the precursors of S0's in the case of amorphous systems, and ellipticals in the case of interacting galaxies.

Data Analysis and Results

The Far-Infrared luminosity of 60μm Peakers spans a range of four orders of magnitude, with a median value of $3x10^{10}$ $L_{\odot}$. This median value is a factor of 2 greater than the Bushouse (1986) interacting sample and 10 greater than the control sample of isolated spirals. (Fig.1) The lowest luminosity objects - IIZw40 and NGC5253- are well studied, nearby prototypes of amorphous galaxies. The highest luminosity sources are ultraluminous galaxies ($L_{FIR} > 4x10^{11}$ $L_{\odot}$), which are dust-enshrouded quasars (Frogel et al. 1989), and presumably are the result of a recent merger/interaction event.

All of the 60μm Peakers are emission line galaxies that are HII region-like (36%), Seyfert type 2 (54%), and Seyfert type 1 (10%). A catalog of the spectra is in preparation (Vader et al 1990).

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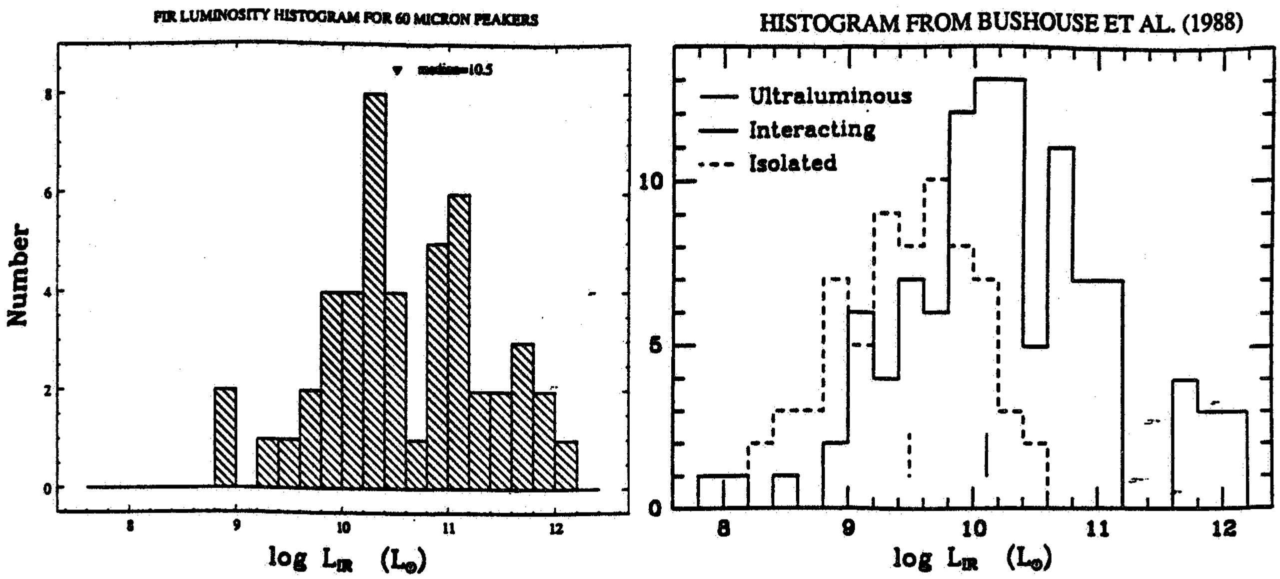
2 Guest Investigator Very Large Array, N.R.A.O., operated by AURA Inc., under contract with National Science Foundation

Figure One



Centrally concentrated activity was shown for all galaxies in our sample for which Hα imaging was obtained. The galaxies observed thus far have 80% of the total measured Hα flux contained within a region which is ~0.8 kpc to 3 kpc. On the other hand we find that in the B broadband filters the galaxies are more diffuse - 80% of the blue flux is contained in a region 1.5 to 4 times the size of the Hα emission line region (Table I). We compare the Hα flux measured from our CCD images to those determined from our nuclear spectra, and find agreement to within a factor of 2. In Fig. 2 we plot the Hα flux (corrected for galactic and internal reddening) versus the far-infrared flux. For the 60μm Peakers, the ratio of the FIR to the Hα luminosities is fairly constant, and is intermediate between that of optically selected spirals (Persson and Helou 1987), and interacting galaxies (Bushouse 1987). The lower values of $L_{FIR}/L_{H\alpha}$ for optically selected spirals is due to the absence of a dust obscured central source, while the higher values for the strongly interacting sample may be understood in terms of a cirrus component which is insignificant in the 60μm Peakers.

We can now use the far-infrared and Hα luminosities to calculate the covering factor of the central active source. The expected ratios of the Lyman continuum luminosity, L_{UV}, to Hα luminosity depends on the UV spectral energy distribution. Values of order 30 are obtained for both OB-star clusters (Mezger et al. 1974), and non-thermal sources (cf. Heisler et al. 1989). Taking into account that about 60% of the total UV luminosity is directly absorbed by the dust one expects $L_{60\mu} \simeq 45 L_{H\alpha}$ for optically thin dust, as is observed for normal HII regions. The UV luminosity inferred from $L_{H\alpha}$ represents a fraction 1-f of the total UV luminosity and, given that in the optically thick case $L_{60\mu}/L_{H\alpha}=45f/(1-f)$, we find a typical covering factor of about 80%.

Table I

IRAS NAME	$R(H\alpha)_{80\%}$ (kpc)	$R(B)_{80\%}$ (kpc)
05570-8123	0.87	1.54
06488+2731	3.27	6.94
08014+0515	0.98	3.06
09497+0122	0.85	1.67
10567-3323	3.51	5.12
13329-3402	0.35	1.51
14082+1347	3.24	6.52
14167-7236	1.54	4.97
16380-8120	1.25	2.38
183343-6528	1.31	3.62
20253-8152	1.24	3.77
20481-5715	3.39	6.14

An estimate of the location of the dust can be obtained by assuming that the dust is concentrated in a spherical shell of radius r centered on the nuclear source, in which case

$$r = 440\left(\frac{50K}{T}\right)^{5/2}\left(\frac{L_{60\mu}}{10^{10}L_{\odot}}\right)^{1/2} \text{pc.}$$

For a dust temperature of 50K (inferred from the 60 and 100μm fluxes for dust with emissivity proportional to frequency, and $L_{60\mu} = 10^{10}$ to 10^{12} $L_{\odot}$) this yields radii in the range 0.1 to 1kpc, which is comparable to the size of the narrow line region in Seyfert galaxies, and suggests that the obscuring dust is close to the nucleus. The close proximity of obscuring dust to the central source points towards the relative youth of central activity in these objects. The 60μm Peakers are generally kiloparsec-scale radio sources, and some of them show dust obscured Seyfert 1 nuclei in polarized light (Miller and Goodrich 1987; Kay and Miller 1989), which further attests to the youth of the central activity.

Figure Two

FIR Versus H-alpha Fluxes

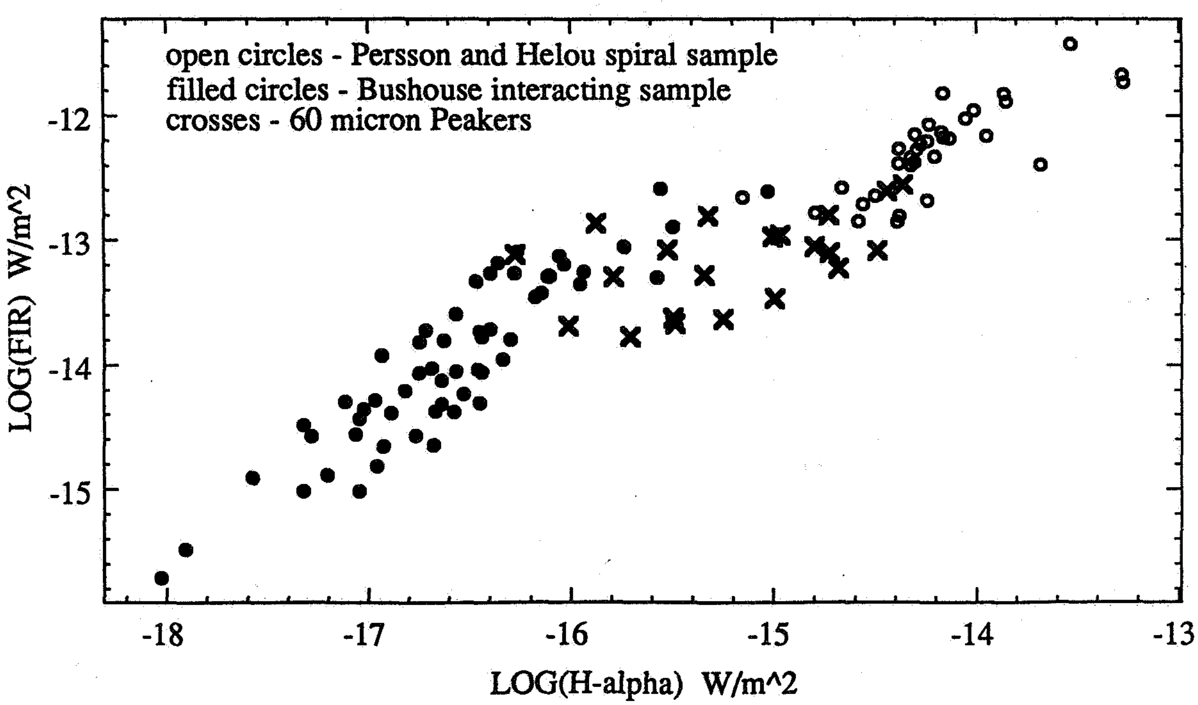
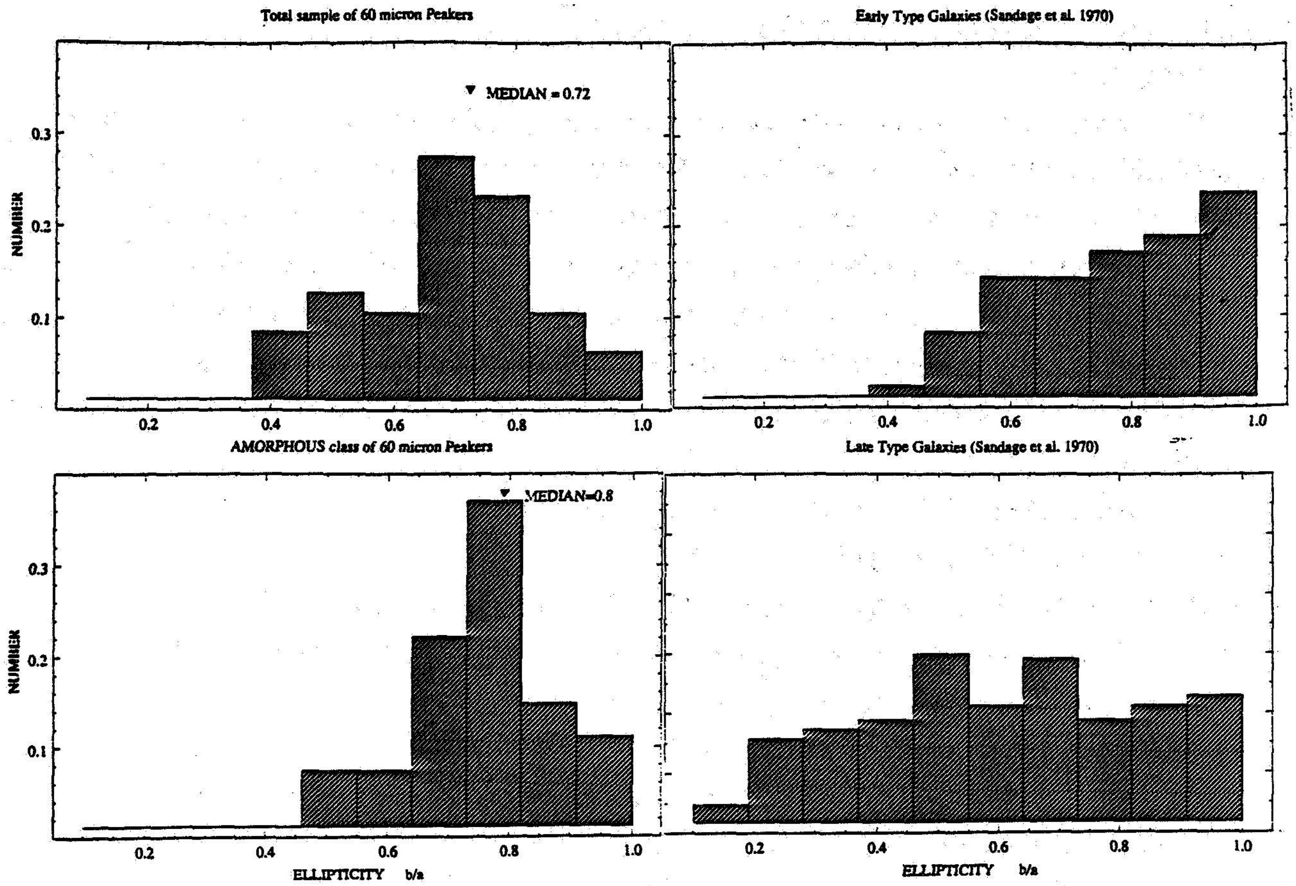


Figure Three



The optical morphologies of the 60µm Peakers can be classified as having a disturbed appearance (25%), or as having a smooth light distribution (70%). The remaining 5% of the 60µm Peakers are normal spirals. The amorphous, S0's, and early type galaxies have all been combined into a class of objects possesing a smooth light distribution, because the above distinctions are not clear cut. For example NGC5253 is a prototype amorphous galaxy, but has also been classified as E and S0 by others. Nearly half of the amorphous galaxies show evidence for a recent interaction/merger event (shells,rings, dust patches). This classification issue can be further addressed by examining the ellipticities of the galaxies.

We have measured the apparent ellipticity of the 60µm Peakers at an isophotal blue magnitude of approximately 22 mag/arcsec^2. Ellipticity distributions are shown in Fig. 3. A chi-squared test tells us that to a confidence level better than 99%, the whole sample of the 60µm Peakers does not have the same ellipticity distribution as either early or late type galaxies (Sandage et al 1970), and similarly when one considers only the amorphous sytems. Preliminary results indicate that the amorphous galaxies have surface brightness profiles consistent with S0's. We suggest that the amorphous galaxies in our sample are the precursors of S0 galaxies, and, as has been proposed by others (eg. Toomre and Toomre 1972), the strongly interacting galaxies are precursors of ellipticals, some of which may develop into strong radio sources.

Conclusion

We have presented evidence that the activity in 60μm Peakers is centrally concentrated and heavily obscured at optical wavelengths. We propose that nuclear activity in these galaxies is a recent phenomenon, and our data supports numerical simulations that show that an interaction/merger event can drive gas to the center of a galaxy in a short time scale (~10^8 yrs), and provide fuel for an active nucleus and/or intense centrally concentrated starburst (eg. Hernquist private comm., Noguchi 1988). Our results suggest that 60μm Peakers may be the precursosrs of S0's in the case of amorphous galaxies, and ellipticals in the case of strongly interacting systems.

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DISCUSSION

Kennicutt:
1. Have you compared the properties of your 60 μ selected sample to other surveys of hot IRAS galaxies based on 25 μ emission?

2. Is there any confirming evidence from the morphologies or kinematics of these galaxies for the idea that they are in early stages of activity?

Heisler:
1. The fractions of Seyfert and starburst galaxies in 60 μm peakers are fairly typical for IRAS galaxies with warm 60 μm/25 μm colours.

2. We do not have kinematical data. The morphology of the objects indicate a recent interaction. The evidence for an early stage of activity is the centrally concentrated activity, compact central radio source (~ kpc scale), and a dust-enshrouded central source which is still close to the nucleus and thus fairly warm and producing the warm FIR colours.

Sulentic: One group of 60 μm peakers is the amorphous class of galaxies. We have obtained spectra of another member of this class NGC 2777, and find it to have a remarkably early (A type) absorption spectrum. Other galaxies in this class also show such a population. Has anyone observed an old stellar component in any of this class?

Goudfrooij: You showed from your two-colour plot that the galaxies in your sample are reddened by an amount of E(B-V) = 0.4. Do you also find this value when determining the Hα/Hβ ratios in your optical spectra? Does the difference of the two E(B-V) values (if present) vary with the type of emission-line activity of the galaxy?

Heisler: The Hα/Hβ ratios indicate an average internal reddening of E(B-V) ~ 0.5. The emission-line activity type of the galaxy does not seem to affect the E(B-V) value.