LETTERS TO NATURE

PHYSICAL SCIENCES

Infrared Photometry of Markarian 231

SEVERAL lists of galaxies with ultraviolet continua have been published by Markarian[1-3] and Markarian and Lipovetsky[4]. Approximately 10% of these objects are spectroscopically similar to Seyfert galaxies. Sargent[5] has pointed out that Markarian's method of searching with an objective prism tends to select those Seyfert galaxies where the nuclei, with their characteristic blue colours, contribute most of the light. Thus, the Seyfert galaxies on Markarian's lists tend to have more luminous nuclei than the classical Seyferts.

Markarian 231 is such a Seyfert galaxy with a very luminous nucleus. Arakelian *et al.*[6] find an emission redshift of $z=0.041$. Using a Hubble constant of 50 km s^{-1} Mpc^{-1} and the photographic magnitude 14.1 given by Zwicky and Herzog[7], we find an intrinsic photographic magnitude $M_p = -22.9$. (The value $M_p = -19.8$ given by Sargent[5] is apparently based on a typographical error in Markarian's paper[3] pointed out by Adams and Weedman[8].) The nuclei of classical Seyfert galaxies have values of M_p of the order of -18. The high luminosity of Markarian 231 is more like that of quasistellar objects, and multiple absorption lines displaced from the emission lines[8] are common in quasistellar spectra.

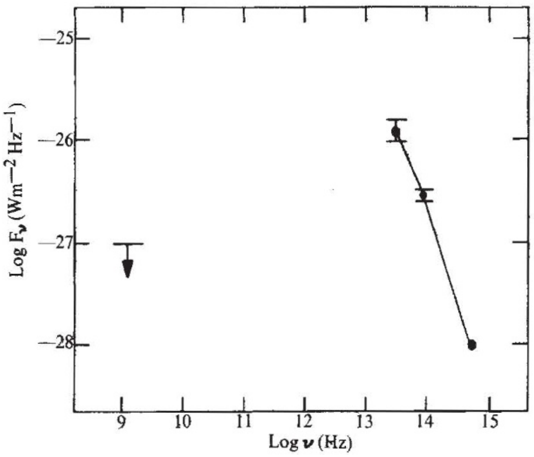

Fig. 1 Spectrum of Markarian 231. References to the measurements are given in the text.

We have observed Markarian 231 in the infrared to gain a better understanding of the energy emitted by this object. Observations were made with a liquid helium cooled, gallium-doped germanium bolometer at the 60-inch Tillinghast reflector of the Smithsonian Astrophysical Observatory. The photometry employed filters with effective wavelengths of 3.5 and 10.8μ and with passbands of $\Delta\lambda = 1\mu$ and 6μ respectively. The object was observed on May 14 and 15, 1972. Flux from both the disk (12 arc s diameter) and the star-like nucleus entered the 9 arc s aperture.

The results are shown in Fig. 1. The uncertainty is the standard deviation of the mean of the integrations, and the calibration of the photometry may be uncertain by an additional 20%. Two other measurements are included in the figure, the photographic magnitude[8] and the radio emission[9,10]. No radio source is found at the position of Markarian 231. The upper limit of 0.1 flux unit at 1,415 MHz is derived from the Ohio V radio survey[10].

Because the flux is rising toward longer infrared wavelengths, where the object has not been observed, we cannot determine the luminosity precisely. A conservative estimate can be based on the observed flux in the 8–14μ band. The total luminosity may be proportional to this flux[11]. The flux between 8–14μ is 1.8×10^{-13} W m^{-2}; this gives a power of 1.2×10^{45} erg s^{-1} based on the redshift $z=0.041$ and a Hubble constant of 50 km s^{-1} Mpc^{-1}. This power is a factor of 1.3×10^6 greater than the Galaxy, a factor of 18 greater than NGC 1068, and only a factor of 35 smaller than 3C 273 in this band. Indeed, the 8–14μ power of Markarian 231 is greater than the total luminosity of the galactic centre by a factor of 3.8×10^3 (see ref. 11). Thus Markarian 231 is the most luminous galaxy yet observed. These observations provide additional support for the hypothesis that similar physical processes are taking place in the nuclei of galaxies and in quasistellar objects.

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Plate Motions relative to the Deep Mantle and the Development of Subduction Zones

THE development of subduction zones may depend on the motion of the two converging lithospheric plates relative to the underlying deep mantle. It is likely that the plates move much more rapidly than the underlying mantle[1-4], the return flow being diffused through a large region[1,5]. The deep mantle is thus nearly stationary and the horizontal motion of