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Quasi-Stellar Objects

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Quasi-stellar objects

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Our knowledge of the infrared emission from quasi-stellar objects is developing rapidly at the present time so I shall not give a systematic survey of the subject. I prefer rather to mention what appear to be the highlights of our present knowledge. First among these highlights comes the behaviour of 3C 273 B. This, the first quasi-stellar radio source to be discovered (redshift $z = 0{\cdot}158$, Schmidt 1963), emits more energy at infrared wavelengths than at all other wavelengths combined. The first infrared measurements were made by H. L. Johnson (1964) at wavelengths of 0·87 μm (I filter) and 2·2 μm (K filter), using the 28 in. telescope of the Lunar and Planetary Laboratory at Tucson, Arizona, and a PbS cell. Measurements at longer wavelengths have since been made (Low & Johnson 1965), but already Johnson was able to state that the infrared spectrum of 3C 273 B was unlike that known for any star, or as it turned out (Johnson 1966) for any normal galaxy. The spectrum is relatively flat from the ultraviolet to the red, begins to rise in the vicinity of the I filter and continues to rise out to the K filter. The later measurements of Low & Johnson (1965) confirmed this result and extended it out to 10·4 μm (N filter) where the spectrum is still rising. The spectrum of 3C 273 is shown in figure 1 which is taken from the paper of Low & Johnson (1965). (A refers to the jet, B to the quasi-stellar source, and C to a hypothetical stellar contribution to the optical part of the spectrum.)

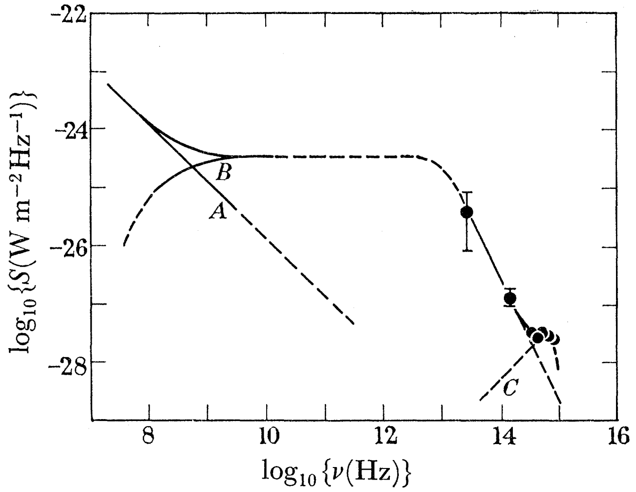

Figure 1. The spectrum of 3C 273. (From Low & Johnson 1965.)

More recent infrared observations of other quasi-stellar objects with $z < 1$ have indicated that 3C 273 B is unusual in having a rising spectrum as one goes from optical to infrared wavelengths. In fact, so far it is unique among such objects in this respect. One is reminded of the fact that 3C 273B is unusual in other respects also: when one seeks a correlation between two observable properties of quasi-stellar objects it often stands out as an exception.

It seems likely that the origin of the infrared radiation from 3C 273 B is the synchrotron mechanism. If one tentatively takes about 1 G for the magnetic field strength, as is suggested by the radio variability and consideration of the inverse Compton effect (Rees & Sciama 1966; Pfleiderer & Grewing 1966; Hillier 1966) then the responsible electrons

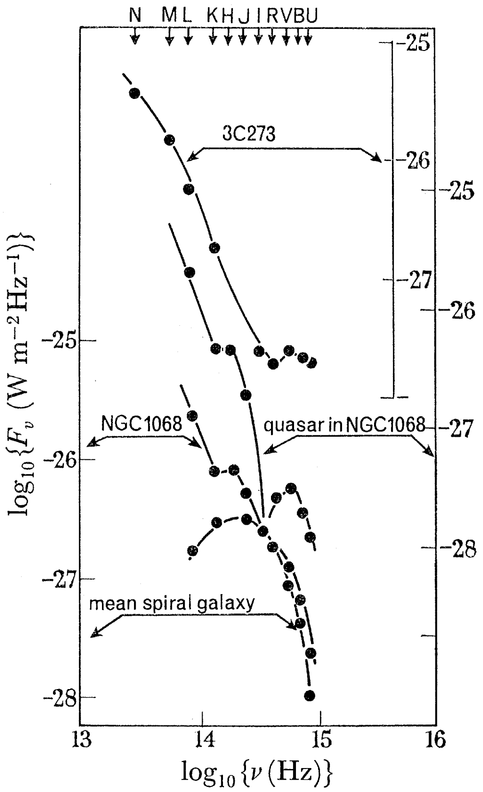

FIGURE 2. Comparison of fluxes of NGC 1068, 3C 273 and a mean spiral galaxy. (From Pacholczyk & Wisniewski 1967; the fluxes for 3C 273 were taken from Low & Johnson (1965) and Low (1966).)

would need to have energies in the vicinity of 10 GeV and an energy spectrum which is rapidly falling. However the synchrotron lifetime of such electrons would be only a few hours, so a continuous injection or acceleration process would be needed. In this connexion it is interesting to note that whereas 3C 273B varies appreciably at radio, millimetre and optical wavelengths no variability has yet been detected at infrared wavelengths (although in view of the paucity of data, short-lived outbursts may have been missed) (cf. also Shklovsky 1966).

Although it is strictly outside our subject, we may mention that the nuclei of some Seyfert galaxies, which in many respects are like relatively feeble quasi-stellar sources (Burbidge & Burbidge 1965; Shklovsky 1966), have infrared spectra similar to that of 3C 273B. In figure 2 are shown the results of Pacholczyk & Wisniewski (1967) for the Seyfert galaxy NGC 1068, together with the spectrum of a mean spiral galaxy of the same I

magnitude and also of 3 C 273 B (the *L* and *M* points for which are due to Low (1966)). Subsequent measurements of NGC 1068, by Low & Kleinman (1967) at 22 μm show that its spectrum is still rising and that its observed intensity still exceeds that of 3 C 273 B at the same wavelength. Similar behaviour is shown by other Seyfert galaxies, though not by all. Clearly further investigations of this remarkable phenomenon are urgently needed.

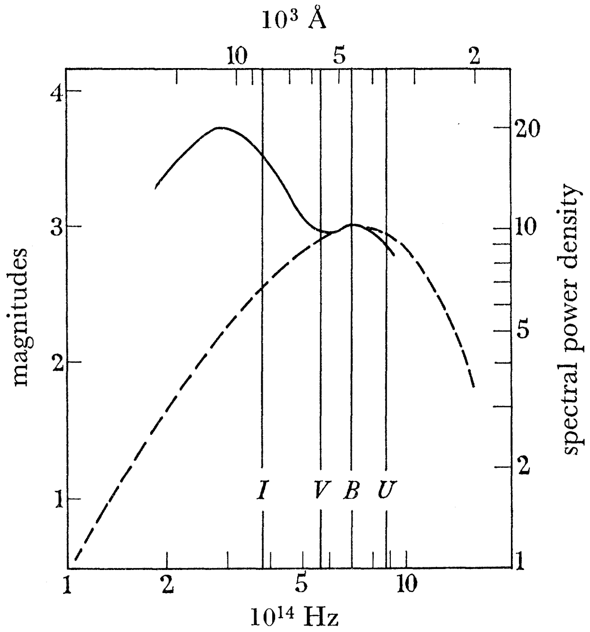

FIGURE 3. The average composite spectrum of QSO's plotted for a redshift of two (——) and the 12000 °K blackbody spectrum (– – –). (From Braccesi 1967.)

The final highlight I wish to discuss is the use of *I* plates as a rapid method of discovering new quasi-stellar objects. Sandage's attempt to use *U*, *B*, *V* plates led to the discovery of radio-quiet quasi-stellar objects, but is not very efficient because the majority of objects with quasar-like colours turned out to be hot stars. The continuous spectrum of such stars is like that of a blackbody at about 10^4 °K which is relatively weak in the infrared. By constrast, the spectrum of a typical quasi-stellar object (Sandage 1966) of large redshift ($z \geqslant 1$) rises in the near infrared, because of the peak in its intrinsic emission in the ultraviolet (figure 3). This led Dr A. Braccesi of Bologna (1967) to propose that *U*, *B*, *I* plates could be used to identify quasi-stellar objects of large red shift in a systematic manner (figure 4). Braccesi has made a preliminary test of the method using the 48 in. Palomar Schmidt telescope, and has singled out 194 candidates in a $6° \times 6°$ field near the North Galactic Pole. I understand that spectra have recently been obtained for five of these candidates, and that four of them are quasi-stellar objects. If this success rate can be maintained*, it should be possible to identify thousands of quasi-stellar objects instead of the hundreds now known. Their study can then be put on a proper statistical basis.

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* (*Note added in proof.*) The score is now fifteen out of sixteen, many of which, however, have relatively small red shifts. (A. Braccesi, R. Lynds and A. Sandage 1968 *Astrophys. J.* **152**, L105).

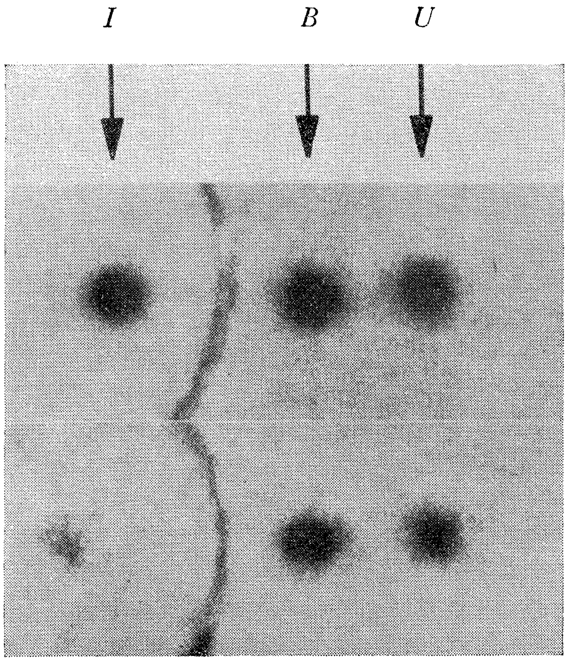

Figure 4. Composition of the U, B and I images for two objects. The lower one is a star, the upper one a suggested quasi-stellar object. Notice how strong its infrared image appears, although the star shown for comparison is quite a reddish one. (From Braccesi 1967.)

I am grateful to Dr A. Braccesi for sending me his results before publication and for allowing me to mention them.

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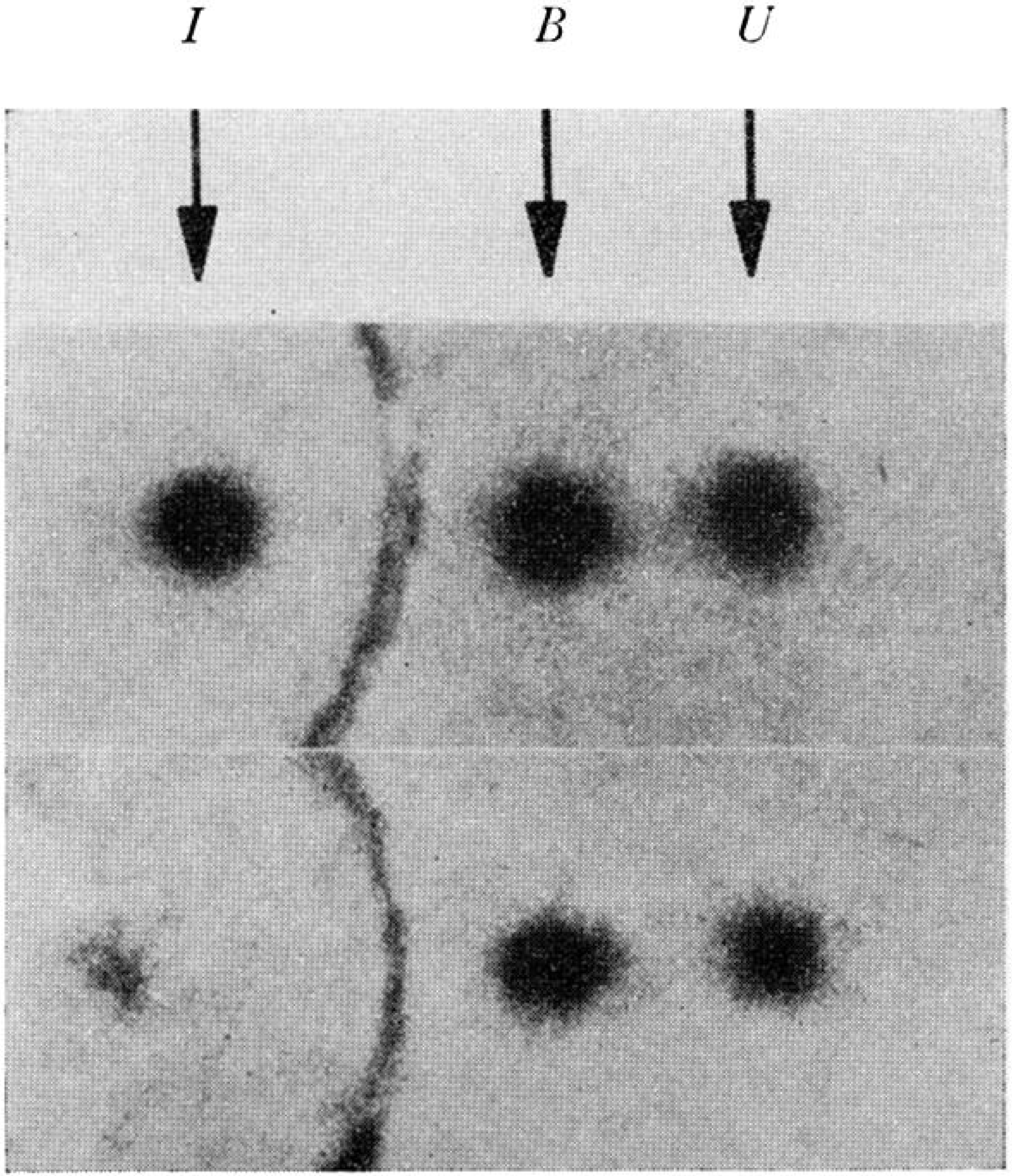

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