For R.A.S.S Halifax
March 25 1964

3 C 48 AND CLASSMATES

In December 1963, there were four or five objects adjudged to be of the same class as 3 C 48 (Greenstein 1963). In January 1964, three more were added to the list (Ryle and Sandage 1964)

The latest communication on the subject was published February 8, 1964. It states that "from the analysis of the emission lines in the spectra of the radio stars it follows that they are the remnants of star-like objects with a mass of about 10^8 $M_\odot$ which exploded about 10^5 years ago" (Shklovsky 1964)

3 C 48 (in Triangulum) aroused general interest after the unscheduled paper of Sandage at the 107th meeting of the American Astronomical Society held in New York City in December 1960 (Sky and Telescope 1963). A direct plate had been taken with the 200-inch telescope of the radio position of 3 C 48. As near as one could expect to the position there was a 16th magnitude star, and nothing else any closer. Associated with the star was a faint wisp of nebulosity, running 3" nnorth of the centre of the star to 9" south of it, and extending to about 2".5 on either side of the centre of the star. The surface brightness of the nebulosity was about 23rd maghitude per square second of arc. The radio source seemed to be a star. This, in itself, was a surprise, because, in 1960, the reception of radio-wavelength radiation from stars (other than the Sun) had been pretty well ruled impossible. (Matthews and Sandage 1963)

3C48 Mag 16.2

In October 1960, two spectrograms of 3 C 40 were taken at Palomar. The only prominent features of the spectra were several strong, very broad, emission lines. There were no strong emission lines of longer wavelength than 5000 A. The three strongest lines were at 4686, 4580 and 3832 A of which the last named was the most striking feature.[1] The lines could not

1. Later shown to be the lines 3426 (NeV), 3346 (NeV) and 2798 (Mg II) redshifted 0.367

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be identified with any plausible combination of red-shifted emission lines. The hydrogen line at 6563 A was definitely absent, and the existing lines could not be readily associated with other hydrogen lines.

The following night, photometric observations were made, which gave B - V = + 0.38 and U - B = - 0.61. That is the star has a numerically greater magnitude when observed through a blue filter than when observed through a yellow filter, and a numerically smaller magnitude when observed through an ultraviolet filter than when view through through a blue filter. This means that it looks brighter through a yellow filter than through a blue, and brighter through a blue filter than through an ultraviolet. This makes it quite different from ordinary stars and galaxies (Matthews and Sandage 1963). Blue main sequence stars have both B - V and U - B negative, and red main sequence stars have both positive (Johnson and Morgan 1953). 3 C 48 is a yellow star, which appears much brighter through a blue filter than would a main sequence yellow star. Its color indices remind one of, but are not identical with, those of old novae.

At Palomar an effort was made to resolve the optical image of 3 C 48. A series of exposures were made at the 200-inch prime focus. The image of 3 C 48 on all plates was sharp, and similar to the images of stars of the same apparent magnitude on the plates. Its image did not look like that of a galaxy.

The astronomers assembled in New York, in December 1960, had no acceptable solution to the problems posed by 3 C 48 . But the question was raised, could it be, in spite of appearances, a distant galaxy ?

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Back at Palomar, It was decided to try a check on the distant galaxy theory. If it was a distant galaxy, it would show no proper motion. If it did show proper motion, the galaxy theory would be ruled out. A plate was taken with the 48-inch Schmidt telescope, with the telescope set to take an exact reproduction of a plate taken in December 1949 for the original Palomar Sky Survey. The plate taken in January 1961, showed no evidence of 3 C 48 having moved, relative to neighboring comparison stars, since December 1949. A change of 0".5 could have been detected. Therefore, in the 11-year ingterval, the proper motion was less than 0".05 per year. Its distance could be anything greater than 200 light-years.

Thereafter, the brightness and color of 3 C 48, was checked off and on. From Oct 24, 1960 until Dec 12, 1963, its visual maghitude to vary, most irregularly, about 0.19 on either side of 16.25. During the same interval, its color indices varied about 0.05 about 0.43 for B-V and 0.57 for U-B. (Sandage 1964).

Meanwhile, 3 C 48 had been found on 75 Harvard plates, 7 of which were for the years 1899 to 1924, and 68 for the years 1933-49. There not found any evidence of systematic variation int the photographic magnitude of 3 C 48 over these years, and there was no spordic change exceeding 0.3 magnitude. (Smith and Hoffleit 1961). This ruled out the possibility of 3 C 48 being a nova which freached its maximum in these years.

Since March 1962, ~~two other radio sources~~ there have been studied optically two other radio sources which seem to have stars at their centres. These are 3 C 196, an 18th magnitude object in Lynx, and 3 C 286, a 17th magnitude object in Canes Venatici. Photometrically, they resemble 3 C 48. The spectrum of 3 C 196 is continuous, with no prominent features. The spectrum of 3 C 286 shows an emission line at 5170 A. (Matthews and Sandage 1963)

The great break-through came when another radio-source, 3 C 273, was studied optically. Attention was called to 3 C 273 by the results of observations of occultaions of it by the moon. These were made in Sydney, Australia. Initiating them was Cyril Hazard who had been at Jodrell Bank. When at Jodrell Bank, Hazard had observed the occultation of 3 C 212, on December 8, 1960. On that occasion, as was to be expected, as soon as the front limb of the moon touched the position of the radio source, radio reception ceased, as though it had been switched off. At the instnt of emersion, the reception came back, as though it had been switched on again. (Hazard 1961).

The occultations of 3 C 273, observed at Sydney, were on April 15, August 5 and October 26 1962. On April 15, only the emersion was observed; on August 5, both the immersion and emrsion were observed; and on October 26 only the immersion was observed. The observation of August 5 was the most spectacular. About 27 seconds before the expected time of immersion, the reception suddenly dropped in intesity, but was not completely switched off. Then, at the time of immefrsion of the star, reception ceased completely. At emersion, the process was reversed. First partial reception returned,

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then total reception. The evidence was that the radio source was labelled B really double. One centre/coincided with the position of the staf, A, the other, was about 19".5 south-east of it. (Hazard, Mackey and Shimmins 1963).

3C273 May 12.8

Optical study of 3 C 273, at Palomar, showed the star to be within 1" of where the radio study put componet B, and the end of a nebulous wisp of light (which commences 11" from the star) to be within 1" of the position given for component A. The spectrum of the star showed lines at 5632, 5032, 4753 and 4595 which could be identified as the Hydrogen lines Beta, Gamma, Delta and Epsilon with a red-shift of .158.[1]

Doubly ionized O = O III

This led to the identification of a line at 5790 as ionized oxygen, O III, at 5007, and to identification of a line at 3239 as singly ionized Magnesium at 2803. (Schmidt 1963).[2] The magnesium line is a very strong line in the ultraviolet spectrum of the Sun, and was first found there on a spectrum photograohed from a rocket. The ionized oxygen line is very strong in the spectrum of the Orion Nebula.

z = 0.367

The spectrum of 3 C 48 was now re-examined. The line at 3832 could be interpreted as Mg II (2798) redsifted .37, and the other two lines 4686 & 4580 would be Ne V 3426 & 3346. A new spectrogram brought out lines at 5098 and 5289, which could be interpreted as O II 3727 and Ne III, 3869, respectively (Matthews and Greenstein 1963). These are two lines found in the Orion Nebula. [Note no Ne lines found in 3C 273]

The conclusions from the evidenceof the spectra is that 3 C 48 is a bright object, in a cloud of gas, distamt about 3000 million lights years and receding at about 30% of the velocity of light. 3 C 273 is distant about 1400 million light years and receding at about 14% of the velocity of light.

1. Redshifted from λ_0 = 4861, 4340, 4102, 3970

2, or 2798 = the Mg II doublet 2796, 2803 (BRB, 1969, Mp 26 R 30)

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The ~~examinatx~~ re-examination of 3 C 196 and 3 C 286 led to the belief that they also are receeding rapidly with comparably distnaces. Another example was then brought to notice, 3 C 147, and it swelled the family to five.

In January 1964, three more radio sources, 3 c 9, 3 C 216 , and 3 C 245 were announced as probably belonging to the same class (Ryle and Sandage 1964).

For a quick check on 3 C 245, atwo photographs of it were taken by the ~~xx~~ 200-inch telescope, on the same plate, the first through a blue filter and the second through an ultraviolet filter, the star, which coincides with the radio postion of 3 C 245 showed up much brighter in ultraviolet than in blue light.