SEYFERT 2 GALAXIES WITH DOUBLE NUCLEI

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ABSTRACT. At least two southern Seyfert 2 galaxies show a double peak in their [OIII] line profiles. Spatial spectroscopy shows each peak to associate with a separate Seyfert 2 nucleus. Separations are of the order of 1 arcsec (1 kpc). The implications and the status of these objects are discusssed.

1. INTRODUCTION

When the [O III] emission-line profiles of Seyfert 2 galaxies are examined with a spectral resolution approaching 10^{-4}, they normally reveal broad wings rising to a monolithic structure with a single peak. However, cases of unusual profiles have been sometimes noted, e.g. the nearly "rectangular" profile of Markarian 622 (Shuder & Osterbrock 1981) and the double peak profile of Markarian 78 (Heckman et al. 1981) - see also Heckman et al (1984). The two cases discussed in this paper both appear to show double peaks, with separations equivalent to 150 km s^{-1}. One of these galaxies (F-427 = ESO 263-G13) is already discussed in the literature but additional material is presented below.

It now appears that such double spectral structure arises, not from a single nuclear region, but from double spatial structure with two nuclear condensations. However, separations are only of the order of an arcsecond (~1kpc). Whilst there is some similarity to the superassociations just described at this conference by Khachikian, one should note that both nuclei show Seyfert 2 excitation and broadening. Keel (1985) has recently reported a similar situation with the Seyfert 2 galaxy NGC 5929.

2. F-427 = ESO 263-G13

The process by which the double structure in the [OIII] region of F-427 was established was a long and painful one! As described in more detail in Fairall & Meaburn (1985), this galaxy showed enigmatic profile variations whereby one of the peaks seemed to appear and disappear - see Figure 1.

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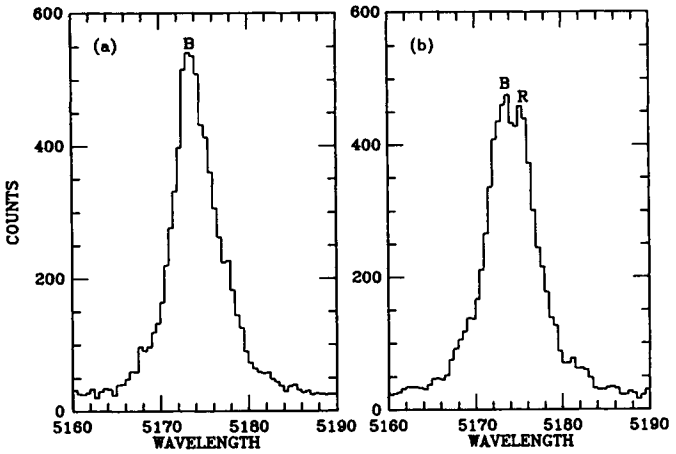

Figure 1. Examples of apparent variations in the [O III] 5007 profile of F-427 as recorded with the SAAO 1.9 m Reflector.

As precautions against spatial variation had been taken, the possibility of temporal variation was considered (Fairall 1983). Since the time scale was so much less than the expected light travel time across the [OIII] region, the question was whether some sort of beaming mechanism - gravitational or lasing - could apply. However, it was afterwards appreciated that remarkable spatial variations could occur in Seyfert 2 line profiles (e.g. Alloin et al. 1984) and somehow the precautions against spatial variation were not enough. Observations by Lucy and Morton (private communication 1983) and the author suggested the B peak favoured the east side of the nucleus and the R peak the west, but this distinction and further detail were best revealed in the Echelle spectrum shown in Figure 2. Most important, this observation showed that the broad base of the line also divided into components and it was possible to extract individual B and R broad plus narrow components (Fairall & Meaburn 1985), that were spatially separated by 0.6 arcsec east-west. The important point is that here are two nuclei within the same galaxy, each of which has both the line broadening and the excitation ratio (5007/Hβ > 8) to qualify as a Seyfert 2 nucleus.

Unfortunately limited observing time during that investigation did not allow the acquisition of a spectrum with the slit N-S (although the imagery did not suggest much extension in this direction). Further, Meaburn has also advocated the use of a wide 4" slit so that no light spills over the jaws of the slit, yet the spectral resolution of the echelle is only slightly degraded - but still more than adequate to split the components. He has obtained such a spectrum in April 1985, and the author is grateful for permission to reproduce it here. It is shown in Figure 3.

The new spectrum shows very clearly that the R component is displaced to the south relative to the B component by ~0.9 to 1.0 arcsec. A North-South displacement was anticipated (Fairall & Meaburn 1985) in so far that it would best explain how slight drifts (in

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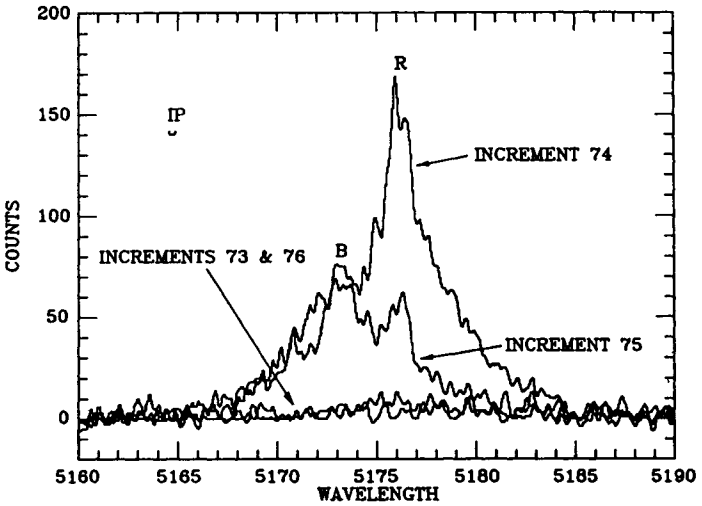

Figure 2. The AAT-Manchester Echelle spectrum of the [OIII] 5007 profile of F-427. The slit, 1 arcsec wide, ran east-west across the nucleus; increment interval was 1.4 arcsec. Dramatic differences are seen in both the peaks and broad base of the line in two successive increments (Incr. 74 = western side).

Declination) of an east-west slit could change the line profile. The new spectrum suggests that observations that failed to record the R peak were offset north, while the observation that produced Figure 2 must have been offset south - this is still somewhat surprising. Equally surprising is the occurrence of what seems to be a new peak in the profile not previously recorded - that labelled B', whilst an SAAO spectrum obtained in 1986 May also seems to show the B peak slightly broadened. However, none of this is to suggest anew that temporal variations occur, but to indicate how underlying spatial/seeing variations can play havoc even when one believes one is holding a slit in a constant position. It is also intended to sound caution in cases of claimed temporal variations in other objects.

The same finding of a north-south profile variation in F-427 has come from an investigation by Wilson & Baldwin (1986) using the CTIO 4 m telescope. Whilst their spectral resolution is lower than even the SAAO observations described above, their spatial coverage and sensitivity is superior and reveals faint extended emission even as far as 4 arcsec from the nucleus. Their conclusions concerning the apparent temporal variations are the same as those expressed here.

To say F-427 has two nuclei is probably an oversimplification. Various minor components can be discerned in the Echelle spectra, such as the B' peak in Figure 3 and the splitting of the R peak in Figure 2. There is also a possibility that the R peak is offset further to the south than the R broad wings since it was the peak, not the wings that was originally seen to vary (and Figure 4 supports this) - yet the R

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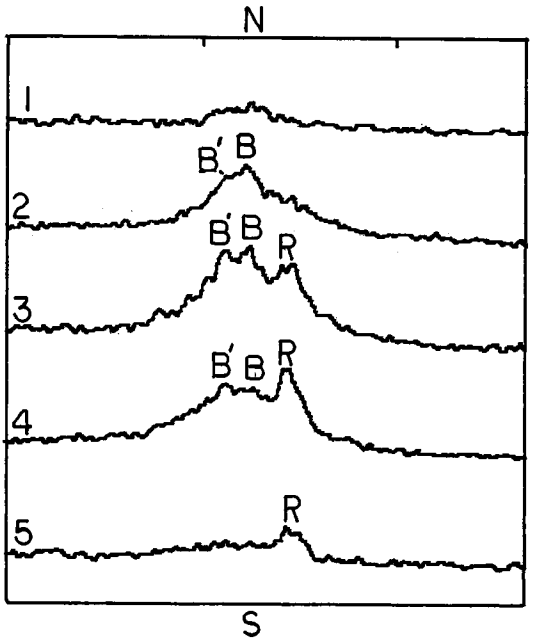

Figure 3. The new echelle spectrum of the [O III] 5007 profile of F-427 provided by J. Meaburn. The slit, 4 arcsec wide, ran north-south; increment interval is again 1.4 arcsec. While the B peak is centred in Increment 3, the centroid of the R peak lies between increments 3 and 4, possibly slightly closer to 4.

broad wings are still separated from the B component(s) and wings (as shown in Figure 2). Thus, while there are two main condensations, the structure of the [O III] region presents a complex, rather than a clean, geometry.

3. F-302 = ESO 157=G23

This galaxy is the second Seyfert 2 found by the author to have a double-peak line profile (Fairall 1985). Further investigations have been made with the SAAO 1.9 m reflector in 1985 September. The situation appears very similar to F-427 as shown in Figure 4 where two [O III] profiles, both made with the slit placed centrally on the galaxy, are superposed. In this case the blueward peak appears to vary and the experience from F-427 strongly suggests it is spatial. Also the redward wing of the line shows a significant variation - akin to that found for F-427 in Figure 2. Once again the implication is that the base of the line cannot be made up from a single broad component, the red wing is independent of the blue wing.

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As yet, imagery and wide slit echelle spectra using an autoguider are not available for this object, but the behaviour of the wings and the occurrence of the double (or stepped) peak in 5 spectrograms so far obtained suggests that some sort of double nucleus is present. Each of the components must have Seyfert 2 excitation level or Hβ would be stronger.

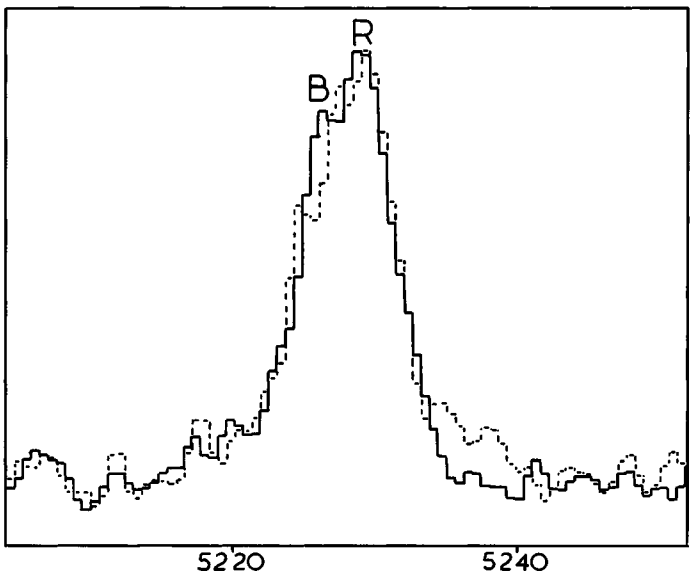

Figure 4. Examples of apparent variations in the [OIII] 5007 profile of F-302 as recorded with the SAAO 1.9 Reflector.

4. IMPLICATIONS ON THE NATURE OF SEYFERT 2 GALAXIES

In Seyfert 1 galaxies, the general similarity in the shape of both broad and narrow line profiles suggests that the narrow line region is physically and dynamically coupled to the broad line region - though obviously the velocities are milder. The implication is that Seyfert 2 galaxies probably host Seyfert 1 nuclei but that the central power sources and broad line regions are either turned off or hidden. What then of these cases of double Seyfert 2 nuclei? The thought of binary active nuclei seems somewhat too revolutionary - literally too, since the question would then arise as to whether one was in the centre or whether they both orbited about the centre of mass of the galaxy; in F-427, the B component appears to coincide with the continuum centre of the galaxy.

An alternative is the argument taken by Keel (1985) for NGC 5929 that the regions are remote from the source of excitation which is the single central powerhouse. Whilst this may retain the excitation, it cannot preserve the line broadening - especially the broad wings of the lines. Why should such regions not then show the lesser broadening of HII

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regions or superassociations? A variation is that adopted by Baldwin and Wilson (1986) in their interpretation of F-427. They suggest bi-polar flow from a central nucleus. While this may explain the two components, the broadening is again the problem. What generates the broad wings of Seyfert 2 lines if the gas is remote from the central active nucleus? Another objection to this interpretation is that in F-427, the B component seems to coincide with the centre of the galaxy, so the components are not symmetrical about the centre. Further the echelle profiles (Figure 2) show details and structures that complicate the geometry.

Indeed it is this messy structure that leads this author to suggest another interpretation. Terlevich & Melnick (1985) have recently challenged the "monster" approach to active nuclei with starburst and "warmers" - bursts of star formation involving supermassive stars that provide high enough photoionizing radiation to produce Seyfert 2 excitation. Supernovae can provide velocities for line broadening. Such a model does not involve a single central engine but suggests complex nuclear structure. The structures of the [OIII] regions of the two galaxies discussed here, particularly with the absence of a single broad velocity component, would seem suited to Terlevich & Melnick's scenario. This is not to say that it must necessarily apply to all Seyfert 2 galaxies, or that all galaxies do not still possess something of a dormant Seyfert 1 style nucleus, but it seems appropriate for the present cases.

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DISCUSSION

HUTCHINGS: What is the velocity separation of your emission line peaks?

FAIRALL: Approximately 150 km s^{-1}.

KEEL: Further to Vera Rubin's comment, in at least the case of NGC 5929, the high-ionization gas is confined to a blob in each side of the dynamical centre. In at least this case, the velocity splitting seems due to rotation, but the spatial structure is not.

FAIRALL: Thank you, that supports the comments made above.

WILSON: A large number of Seyfert galaxies show spatially extended line emission with emission line widths and profiles which vary rapidly with position. An alternative to your suggestion that the two components represent two separate active nuclei is that there is only one "true" nucleus, with spatially extended clouds. Would you care to comment?

FAIRALL: This is possible. As mentioned for F-427, the B nucleus appears to coincide with the centre of the galaxy, the nucleus is offset. Yet each nucleus has the broadening and excitation to qualify individually as a Seyfert 2 nucleus - in fact the offset nucleus appears to be the stronger one of the two. One would not expect circumnuclear "clouds" to have Seyfert 2 excitation.

PETERSON: Have you made any attempt to measure the systemic redshifts of these galaxies (i.e. the absorption-line redshifts)?

FAIRALL: Unfortunately the absorption features have proved much too faint for me to detect (at the dispersion required) with the telescope at my disposal.

RUBIN: Can you be certain that the double velocity peaks do not arise from the two sides of the rotation curve? With a 4" slit, you are sampling about 2kpc on each side of the nucleus. If the rotation curve is very flat, then you might get 2 peaks, one from the approaching and one from the receding velocities. Perhaps spectra in several position angles could be analyzed to see if they are consistent with rotation.

FAIRALL: For F-427, I had assumed the galaxy was seen flat-on, or so close to flat-on, that what we were seeing did not represent the normal rotation of the galaxy. Also, we would normally expect a Seyfert 2 nucleus to coincide with the dynamical centre of the galaxy - and it looks as if the B nucleus does this, rather than being on the approaching or receding sides. The separation of the two nuclei is only 1 arcsec (the 4 arcsec slit was a special observation to ensure no light was lost). However, I find your suggestion most interesting, since I have not previously realised that the 150 km s^{-1} difference could just be the observed component of the rotation. This suggests the second nucleus may simply be following the normal rotation of the galaxy, so that no form of ejection is required. This would then favour a starburst or "Warmer" interpretation.

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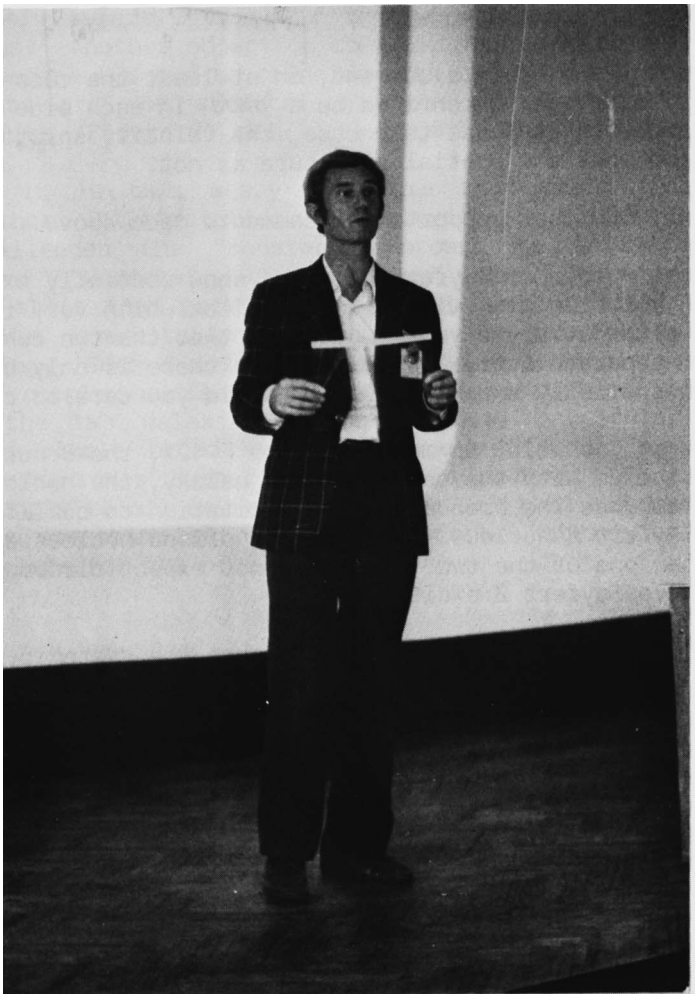

Fairall advertising double nuclei

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