several atmospheric regions, further repeated observations are still necessary over a significant time-scale. Finally, in order to link the observed properties of the LSE to the properties of the subatmosphere, we have undertaken at La Silla a study of the behaviour of the photospheric lines of the star with the CES. This programme is currently in progress.

# The Multi-Faceted Active Galaxy PKS 0521-36

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The southern active elliptical galaxy PKS 0521-36 exhibits a range of nuclear and extranuclear phenomena which is remarkable in a single object which has only been observed in any detail over the last few years. Indeed, if it were situated significantly closer than its 330 Mpc ($H_0$ = 50 km/s/Mpc), it would probably attract more observational and theoretical attention than Centaurus A and M 87 combined. The relationships between its many manifestations of high-energy activity will be the subject of intensive study as new observational techniques become available.

As has so often been the case for southern active objects, attention was first drawn to the galaxy by its optical identification with a Parkes radio source (Bolton, Clarke and Ekers 1965). Higher resolution images suggested an elliptical morphology, but the broad-band colours were anomalously blue, giving the first reason for special interest. The photometric observations of Eggen (1970), showing that it varied by more than one magnitude on a time scale of months, supported the earlier spectroscopic observations of Westerlund and Stokes (1966) and Searle and Bolton (1968), which showed an almost featureless continuum with only very weak emission lines, suggesting a close relationship to BL Lac objects.

## Optical Structure

### *(a) The Jet*

Deeper direct imaging obtained by Danziger et al. (1979) showed a jet-like structure extending about 20 kpc towards the north-west. This has a structure somewhat reminiscent of the jet in M87, although a direct comparison is difficult because of the order-of-magnitude difference in linear resolutions available. Sol (1983) has examined the structure of the jet in more detail: as in M87, it consists of condensations of different surface brightness. We are now fairly certain that in the optical region, all sections of the jet are emitting continuum and not line radiation. In deep CCD images of the object in a narrow-band filter isolating redshifted Hα, the jet does not appear. Nor do emission lines appear in the north-west in long-slit spectroscopy aligned along the jet. This spectroscopy does, however, reveal extended emission elsewhere. Nothing is yet known about the polarization of the jet in the optical band although there is associated radio structure which we discuss below.

### *(b) The Extended Emission*

During the course of long-slit spectroscopy of this object with the UCL IPCS on the ESO 3.6 m Boller & Chivens spectrograph, nebular emission was discovered extending about 10 arcseconds to the east and south-east. This is not the source of the relatively weak emission seen in the integrated spectrum, which comes from a compact region at the nucleus.

In Fig. 1, we show the result of a 40-minute exposure taken with the CCD on the Danish 1.5 m telescope on La Silla through an interference filter with a bandwidth of 32 Å and a central wavelength of 6922 Å, corresponding to redshifted Hα. No continuum subtraction has been done. The picture shows a faint filamentary structure extending north of east and then turning towards the south. The reality of this structure has been established by long-slit spectroscopy with the slit in several different positions. In addition to the eastern filament, the picture hints at a more general, irregular filamentary structure. There is perhaps also a very low surface brightness halo extending out to a radius of ~15 arcseconds. These features merit more detailed study with deeper high-resolution imaging and spectroscopy. The picture shows no structure corresponding to the jet.

Spectrophotometry of the eastern filament, Fosbury (1982) and recent unpublished results, show the gas to be in a low state of ionization with [O III] λ 5007 / Hβ ≲ 1.5. This contrasts

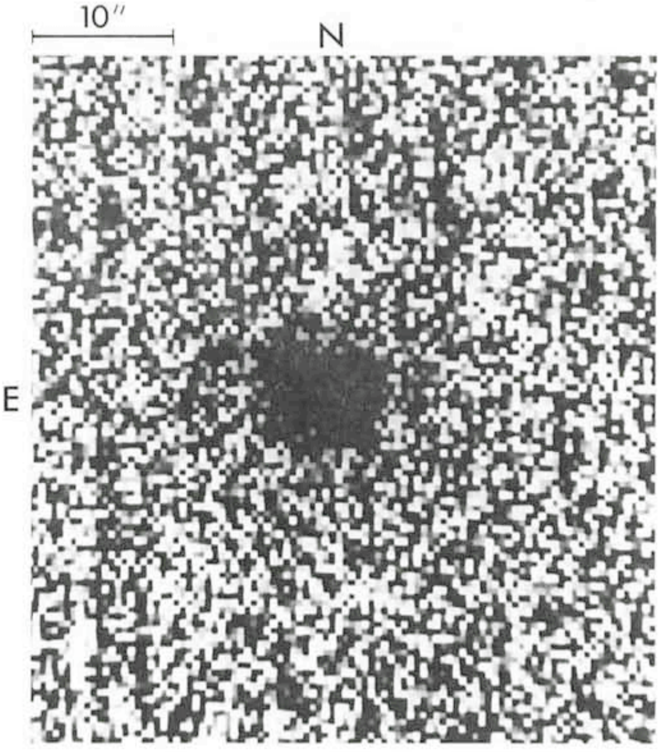


Fig. 1: *A 40-minute CCD exposure of PKS 0521-36 taken with the Danish 1.5 m telescope on La Silla. The filter was a narrow band centred on redshifted Hα (6922 Å). It shows the filament to the east of the galaxy but no feature corresponding to the jet visible on broad-band images in the blue.*

with the nuclear spectrum where this ratio for the narrow line component is close to 3. Little is known yet about the dynamical state of the filamentary gas other than that its internal velocity spread and its velocity relative to the nucleus is less than a few hundred km/s. Attempts to diagnose the ionization mechanism in these outlying regions are hampered by the low signal-to-noise of the spectroscopic observations although we can say that the [O II] $\lambda$ 3727 / [O III] $\lambda$ 5007 ratio is $\gtrsim 2$.

### *(c) The Nucleus*

Apart from the stellar component, characterized by diluted absorption lines of Ca II, Mg I, etc., there appear to be three different regions, each generating its own spectral imprint. There is a low density region of ionized gas, analogous to the NLR seen in most active galaxies. One should be careful to note, however, that a clear diagnosis of the ionization mechanism has not been made from our data because of the difficulty of measuring the important weak lines such as He II $\lambda$ 4686 and [O III] $\lambda$ 4363.

There is a broad permitted line-emitting region whose temporal behaviour has not yet been well defined. This can be seen in the optical Balmer lines and in an IUE observation of broad Lyman-$\alpha$ reported by Danziger et al. (1983). It has been suggested by Ulrich (1981) that the broad-line spectrum had developed during the period between the observations of Danziger et al. (1979) and her own, at an epoch several years later. The equivalent widths have certainly changed during this period, since there has been a dramatic decrease in continuum radiation. There is, however, evidence that the broad lines have increased relative to the forbidden line spectrum. There are no observations to our knowledge which show the complete absence of broad lines. Broad-line variability in Seyfert and radio galaxies is now a well-established phenomenon with many reports in the literature, and detailed observations can be used to place extremely useful constraints on size scales and nuclear masses. An example of the optical spectrum, when the blue continuum was weak, is shown in Fig. 2.

The BL Lac nature of the nucleus is manifested through the variability of this blue continuum and through optical polarization reported by Angel and Stockman (1980). Danziger et al. (1979) decomposed the stellar and power-law components to give a spectral index of approximately −1. Using IUE observations, Danziger et al. (1983) combined UV, optical and IR data, at an epoch when the nucleus was about one magnitude fainter, to give a spectral index of about −1.5 for the non-stellar continuum. This implied steepening of the spectrum with decreasing luminosity needs to be checked at other epochs.

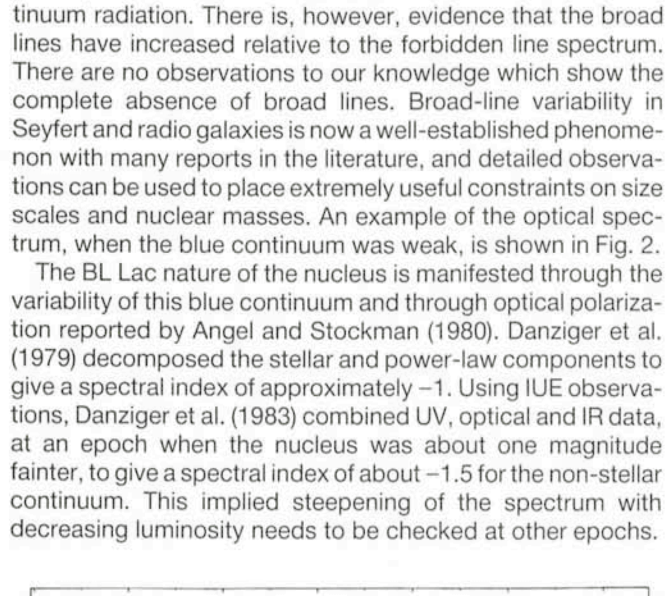


Fig. 2: *A low-resolution IDS spectrum of PKS 0521-36 taken when the nucleus was in a low luminosity state in August 1981. Note the broad Hα and Hβ emission.*

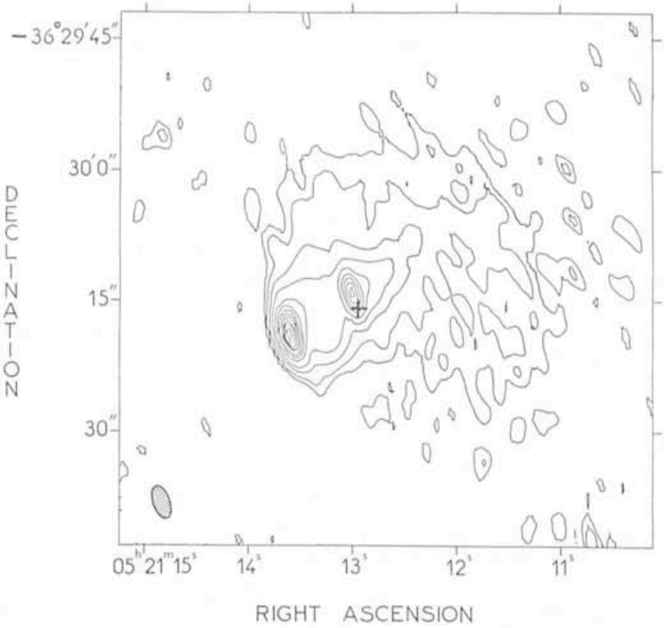


Fig. 3: *A 1.4 GHz continuum map of PKS 0521-36 made with the VLA in New Mexico. The optical nucleus is marked with a cross; the offset is probably due to the poor astrometric reference frame in the south.*

## Radio Structure

Since its discovery, PKS 0521-36 was known to be an extended radio source (Mills, Slee and Hill, 1960). VLA observations have provided a much more detailed picture of its complex structure. A 1.4 GHz continuum map is shown in Fig. 3. It appears to be a triple source with the outer lobes of very unequal intensity. The south-eastern lobe is resolved with a size of about 1 arcsecond while the much weaker north-west component follows closely, in direction and extent, the optical jet. An unresolved, flat spectrum source is positioned at the nucleus of the galaxy. The apparent offset between the radio and optical nuclei is within the range of uncertainty due to the poorly known positions of SAO reference stars in the southern hemisphere. Such comparisons will, in the future, be greatly facilitated by the new Cape catalogue in the process of preparation (Nicholson et al., 1984). The radio nucleus has been resolved at approximately 1 milliarcsecond using VLBI measurements.

A correlation of the radio and optical structures reveals another interesting coincidence. That is between the steep south-east edge of the radio source and the eastern emission-line filament. This is reminiscent of a similar coincidence in Coma A reported by van Breugel (1981) and seen in a number of other galaxies with radio jets (Balick and Heckman, 1982; Danziger et al., 1984; Fosbury et al., 1984). The possible transfer of energy between the radio plasma and the thermal, emission-line gas is of great interest in the physics of radio sources.

The VLA map also shows the extended, low brightness emission having a steep spectrum and a diameter of about 30 arcseconds. The nature of this halo might be associated with the similarly sized structure hinted at by the Hα CCD picture. If this association were real, it would be of great interest.

## X-ray Emission

PKS 0521-36 is an X-ray source (Schwartz and Ku, 1983) as are most BL Lac objects. We do not yet know anything about variability although in the near future EXOSAT observations will provide information. More importantly we do not know whether it is an extended source or not. It could be extended up to a diameter of ~2 arcminutes and would not have been resolved by the one IPC observation from the Einstein Observatory. An extended source might point to a cooling flow giving rise to the condensing filaments that we see as low-excitation filaments and conceivably the diffuse Hα and radio halo.

From our spectroscopy of the filaments alone we can provide an estimate of the total Hβ emission = $9 \times 10^{39}$ ergs/sec. Under the assumption that each hydrogen atom in the cooling flow recombines only once, this estimate converts into an accumulating mass flow of approximately 500 solar masses/year. This is of the same order of magnitude as Fabian and Nulsen (1977) obtained for NGC 1275 (Perseus A). In fact, a number of the other radio and optical properties of PKS 0521-36 remind one of NGC 1275.

At present we cannot assert strongly that the wider environment of PKS 0521-36 supports the idea of an X-ray cooling flow. Certainly it does not belong to a rich group or cluster. There are in the neighbourhood, however, other fainter galaxies whose redshifts are not yet known. And of course we know nothing at all about the possible existence of intergalactic gas clouds in this region.

## Summary

There are many phenomenological details associated with PKS 0521-36, some suggestive ideas and not many clear-cut answers. It is clear, however, that new generations of observing facilities can shed further light on many of the problems alluded to here. The Space Telescope will have imaging capabilities that provide spatial resolution of PKS 0521-36 equivalent to that currently possible for M87 with large ground-based telescopes. It will also provide extended wavelength coverage for studying the jet. Future high-resolution X-ray imaging observations will be necessary and possible.

VLA observations to study the spectral and polarization properties of the various resolved components in this source are under way.

All of this may mean that PKS 0521-36 will in the future attract as much attention as the popular, relatively nearby active galaxies.

## Acknowledgements

We thank Holger Pedersen for the Hα CCD image and Alec Boksenberg, Keith Shortridge, John Fordham and the La Silla technical staff for getting the IPCS operating on the 3.6 m telescope.

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# Observations of High Redshift Mg II and Fe II Absorption Lines in QSO Spectra

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## Introduction

When the first absorption system was discovered in the spectrum of 3C191 by Burbidge et al. (1966) it was immediately realized that the analysis of QSO spectra could bring a lot of information on the large-scale content of the universe. The path length to high redshift QSOs is so large that the line of sight towards such objects is likely to intersect galaxies and intergalactic clouds which will leave their signature in the spectrum. Although many questions remain yet unsolved today, some conclusions emerge from the increasing amount of data. It seems now well established that among all systems, those containing sharp metal-rich absorption lines can be associated with intervening galactic haloes. Arguments are mainly of a statistical nature and come from a detailed study of the redshift distribution of the systems. This function appears to be compatible with absorption by randomly distributed clouds and, moreover, the systems tend to cluster in the same manner as galaxies (Young et al. 1982).

In standard Friedmann cosmological models and in the absence of cosmological evolution of the absorbers, the mean number of systems per unit redshift interval, dN/dz, is expected to be of the form

$$\frac{dN}{dz} = \frac{C \times n_o \times \sigma_o}{H_0} \times \frac{1+Z}{\sqrt{1+2 \times q_0 \times z}}$$

where $n_0$ is the number density of absorbers and $\sigma_0$ their cross section at the present epoch. The knowledge of dN/dz is of great interest since in principle it could yield the value of $q_0$. In fact, over a large redshift range cosmic evolution effects could