EXTENDED EMISSION LINES IN RADIO GALAXIES

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In whatever physical state the gas is found, observations of the interstellar medium in elliptical galaxies are of considerable interest. This is particularly true in the case of radio galaxies where we believe that the gas is an indespensable part of the cause of nuclear activity and plays a role in the origin and the evolution of the radio galaxy phenomenon. In a few cases we are fortunate to find some of the gas to be ionized with a temperature of about 10^4 K where optical spectroscopy allows us to deduce something about the excitation/ionization mechanism, about its chemical composition and about its state of motion. Here I wish to summarize observations of three Southern radio galaxies which show optical emission lines from regions tens of kiloparsecs in extent.

The 14th magnitude elliptical (z = 0.033) identified with *PKS 2158-380* is the brightest member of a small group of galaxies containing about ten members. The radio morphology is double but is unusually asymmetric with the components having a flux ratio of 5. The remarkable feature of the object is a high ionization emission line region with a largest dimension of 30 kpc (H_o = 50 km s^{-1} Mpc^{-1}). Both direct photography and long-slit spectroscopy show the emission to be distributed in an *S*-shaped structure centred on the nucleus. The *HeII* $\lambda 4686/H_\beta$ intensity ratio is about 0.3 throughout the galaxy and the emission is clearly not the result of photoionization by hot stars. Neither are the line-ratios consistent with a shock-heating mechanism and it appears likely that the gas is everywhere photoionized by an active nucleus emitting a non-thermal ultraviolet spectrum. Observations with *IUE* satellite reveal a nuclear point source with a spectral the index of about -1.4. The requirement to ionize gas at large distances from the nucleus does however impose a constraint on the geometrical distribution of the gas: a thin planar disk will not suffice. I believe that the observed gas velocities are the result of rotation in the gravitational potential of the elliptical galaxy but that the present configuration is not one of equilibrium. The hypothesis of a severely warped gaseous disk is consistent with all the data and in particular allows naturally for ultraviolet radiation from the nucleus to travel large distances without significant absorption before intercepting the gaseous sheet. Since dissipation processes would restrict the dynamical lifetime of

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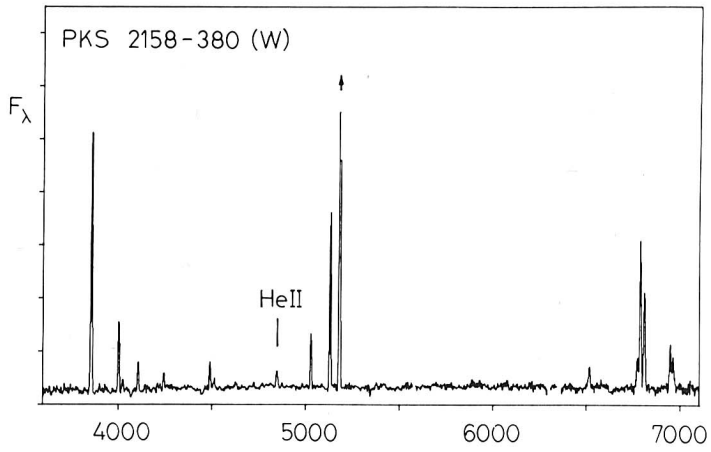
the configuration to at most a few times 10^8 *yrs*, it appears likely that the elliptical galaxy has recently captured and disrupted a small companion whose gas content may now be providing the fuel for the nuclear activity.

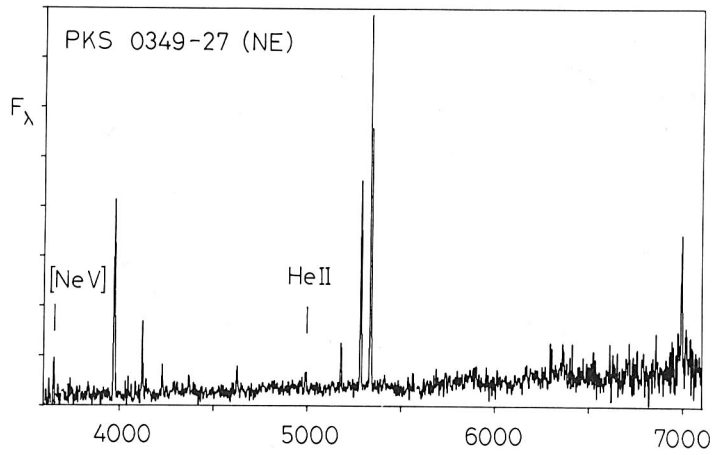
The 16th magnitude galaxy (z = 0.066) identified with *PKS 0349-27* shows even more direct evidence of a recent dynamical interaction for here we can see what appears to be the stripped nucleus of a passing galaxy which has left its gas covering a region over *70 kpc* in extent. Again the ionization state is high with *He II* $\lambda 4686/H\beta \simeq 0.5$ throughout. Although in this case the galaxy is too faint for IUE observations, the line ratios are most straightforwardly explained as photoionization by a non-thermal source. The highly non-equilibrium dynamical state is confirmed by the long-slit spectroscopy which shows approximatley linear velocity radius relations along the three position angles observed. As well as the stripped companion *20 arcsec* to the East, there is another bright elliptical at a projected distance of *140 kpc* to the West and it is likely that the gas giving rise to the emission lines is subject to complex tidal forces. Notwithstanding these complexities, I believe that detailed *2D* mapping of the velocity field of the gas around these ellipticals will provide valuable information about the mass distribution in such galaxies to much greater radii than are possible to reach using other techniques like absorption line spectroscopy.

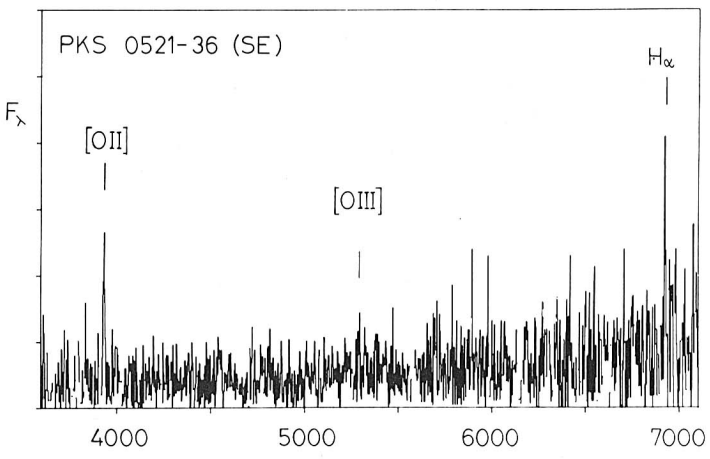
The emission associated with the *BL Lac* object *PKS 0521-36* has a different character. The emission line redshift of 0.055 was confirmed and diluted stellar absorption features at the same redshift were discovered by Danziger *et al.* (1979) who also reported the existence of an optical jet in position angle 305^o with an extent of *10 arcsec*. New observations with the *VLA* at *5* and *1.4 GHz* show the flat spectrum core and a steep spectrum, edgebrightened structure extending *SE* (*pa* 123^o), diametrically opposite the optical jet. An optical spectrum, taken with the slit aligned along the optical/radio jet axis shows extended *[OII]*, *[OIII]* and *Hα* emission peaking at the nucleus and at the position of the steep spectrum radio component to the *SE*. No line emission is seen on the side of the jet seen in the *B*-band photograph which suggests that this is a continuum structure. If the optical jet is indeed a non-thermal continuum then *PKS 0521-36* provides us with an example of a double jet which is spatially, though not energetically, symmetric.

This summary paper is the result of work carried out with many collaborators and has included observations made with a variety of different instruments. I wish to acknowledge all of these people but in particular Alec Boksenberg, John Danziger, Ron Ekers, Miller Goss, David Malin and Peter Shaver. Detailed reports of this work are being published elsewhere.

Danziger, I.J., Fosbury, R.A.E., Goss, W.M. & Ekers, R.D., 1979. Mon. Not. R. astr. Soc., 188, 415.







Representative optical spectra of the extended emission in the three radio galaxies discussed in the text. The spectra are from the University College London IPCS on the ESO 3.6 m telescope in Chile. The ordinate is a relative F_λ scale.

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