astrometry (e.g. proper-motion studies), but it can be very well used for CCD astrometry of faint solar-system bodies.

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NTT Archives: the Lyman α Profile of the Radio Galaxy 1243+036 Revisited

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Abstract

All observations of very high redshift radio galaxies attest to a highly complex interaction between large-scale astrophysical processes as violent and diverse as that of nuclear activity and of cosmogonic star formation. Lyα is seen in emission over scales exceeding galactic sizes and its resonant nature leads by itself to a wide range of phenomena such as absorption lines due to intervening H I gas layers of very small columns, or enhanced dust extinction due to the manifold increase in path length traversed before escape. The resonant nature of Lyα can also manifest itself in emission through the process of Fermi acceleration across a shock discontinuity which leads to a large blueshift of the line photons. We propose that such a process is at work in the radio galaxy 1243+036 (z = 3.6) and can account for the three narrow emission peaks present on the blue side of the profile. The ultimate source of the photons present in those peaks likely consists of a jet-induced starburst of ≥ 5 10^7 $M_\odot$ situated at the position of the radio jet bend. Our investigations illustrate one possible use of the user friendly archival database developed by ESO.

1. General Context

Lyman α is the strongest emission line observed in High-Redshift Radio Galaxies (HZRG). Although the brightness of the line reaches a maximum towards the nucleus, most of the emission is spatial-

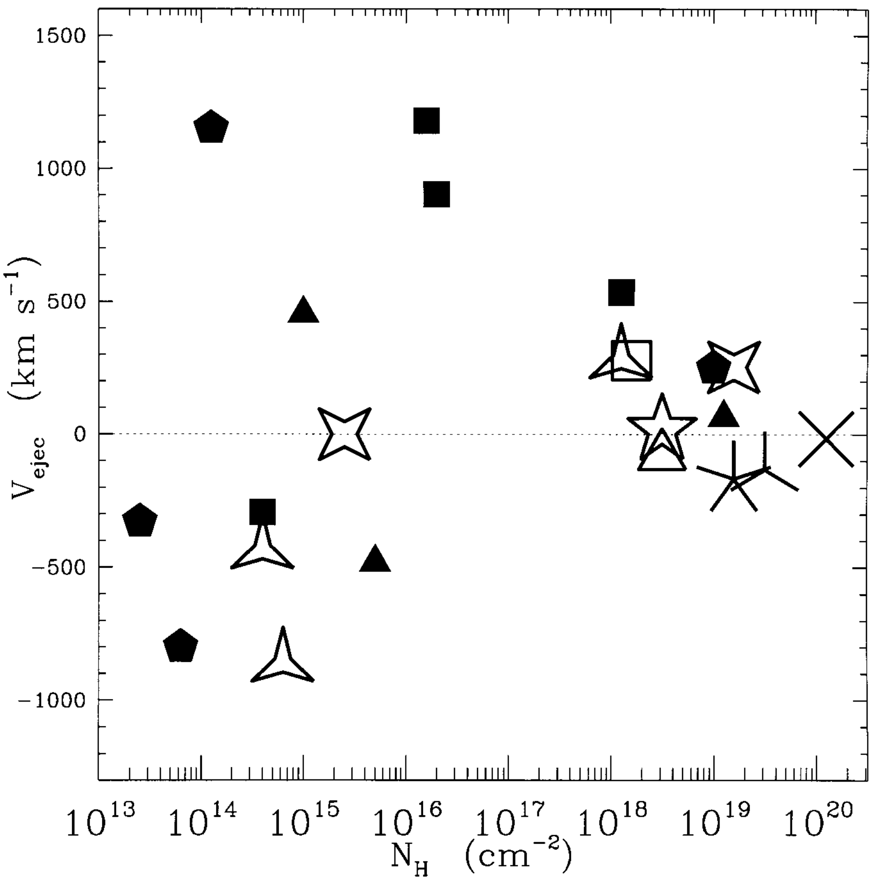

Figure 1: Velocity shifts of the absorbers relative to line centre as measured by van Ojik et al. (1997). Distinct symbols are used to distinguish different objects. For instance, all the four absorbers of 0828+193 are represented by solid squares. Negative and positive ejection velocities are of comparable likelihood. The figure does not contain the absorption dips reported in 1243+036.

ly resolved with the fainter emission extending up to radii 40–130 kpc. The work of van Ojik et al. (1997) shows that the full width at half-maximum of the integrated Lyα profile is in the range of 700–1600 km/s. One striking feature discovered by van Ojik et al. is that out of 18 intermediate-resolution (≃ 3 Å) spectra of HZRG, fully 60% of the objects showed deep absorption troughs superposed to the Lyα emission profile. The H I absorption column density of the dominant absorber is in the range of 10^{18}–10^{20} cm^{-2}. In some cases, more than one absorber is present but with much smaller columns (10^{14}–10^{16} cm^{-2}). An important conclusion reached was that the absorbers were part of the local environment of the parent radio galaxy. The fate and nature of the absorbers are still a matter of debate. If one converts into ejection velocities the absorption trough positions relative to the emission line centre, the smaller columns show some tendency towards higher velocity shifts as shown in Figure 1. Globally, the sign of the velocity shifts is randomly distributed without any strong preference towards either ejection (blueshift) or infall (redshift).

2. The Asymmetric Lyα Profile of 1243+036

The study of van Ojik et al. (1997) reveals that the underlying Lyα emission profiles within their 18 objects sample are remarkably gaussian and symmetric once allowance is made for the presence of the absorption troughs (fitted with Voigt profiles). In this respect, 1243+036 stands as a noteworthy exception with an asymmetric profile due to a significant excess of flux on the blue side. Superposed on this blue excess are narrow features which van Ojik et al. (1996) interpreted as four *absorption dips.* Interestingly, these all arise on the blue side, which is uncommon. The Lyα profile of 1243+036 is displayed in the top panel of Figure 2. Our proposed and variant interpretation is that the blue asymmetry consists merely of three narrow *emission peaks* with little if any absorption at all. This possibility is best illustrated by the dotted blue line of Figure 2 which is the *difference* between the blue half and the smoothed and folded red half of the Lyα profile. It thus becomes apparent that the narrow features which stand out most significantly above noise consist of net emission.

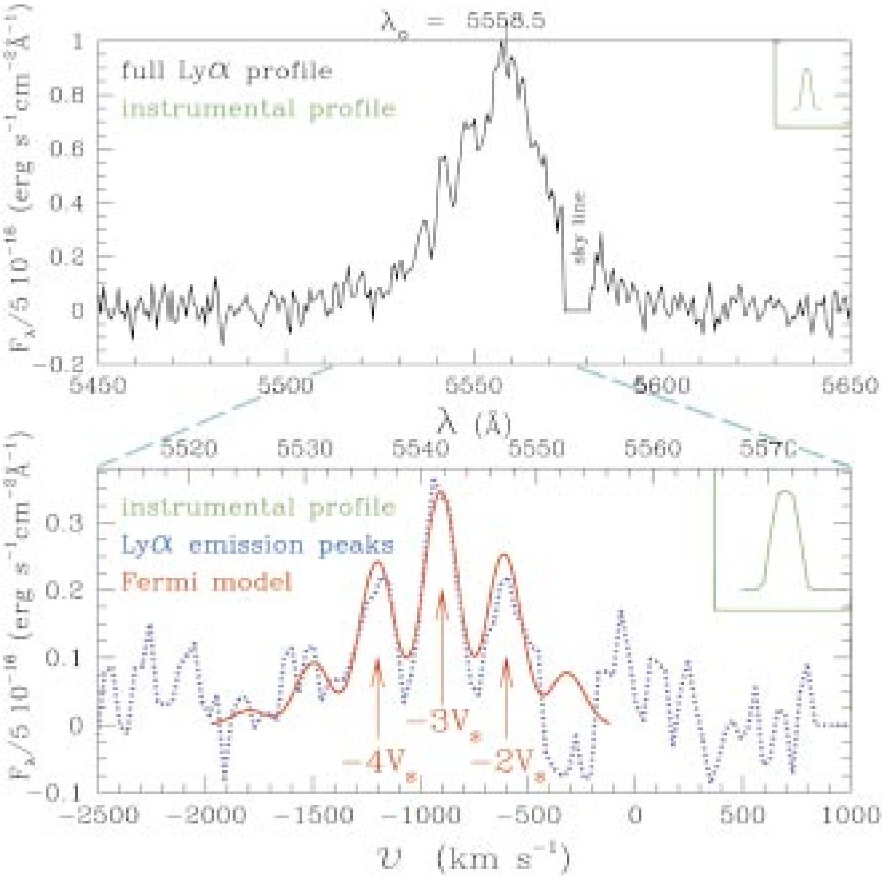

Figure 2: The top panel shows the Lyα profile of 1243+036. Originally taken by van Ojik et al. (1996), the spectrum was retrieved from the ESO archives (http://arch-http.hq.eso.org) and re-reduced by one of us (BJ). Extraction along the long slit was performed using a 7″ window centred on the radio bend rather than on the nucleus (2″ away). The narrow blueshifted features shown in the bottom panel (blue dotted line) were isolated by subtracting the smoothed and folded red side of the profile. The top abscissa is the observed wavelength scale while the bottom abscissa represents velocity shifts with respect to λ_0, the wavelength we attribute to systemic velocity. The red line is a model based on Fermi acceleration across a shock discontinuity moving at 300 km/s. The model was convolved by the instrumental profile which is depicted in green.

3. Fermi Acceleration and the Equidistant Peaks

A study by Neufeld and McKee (1988) of the transfer of resonant Lyα across a shock discontinuity has shown how the repeated scattering of resonant Lyα photons across the shock front can lead to a systematic blueshift of the line. The blueshift can greatly exceed the shock velocity V_s if the H I column density on either side of the shock is very large, thus providing a new and interesting explanation for the blue asymmetric profiles observed in a few radio galaxies.

We have further developed the Neufeld and McKee (1988) model by extending its validity to the regime of smaller columns in which individual emission peaks become identifiable (see Binette, Joguet and Wang, 1998). The close correspondence between the model as represented by the red line in Figure 2 and the emission features is certainly encouraging. Unlike absorption features which appear at random velocities, the three emission peaks occur only in the blue wing, as the Fermi acceleration process would predict. In fact, each successive emission peak corresponds to the incremental blueshift resulting from two scatters – back *and* forth – across the shock discontinuity, with each across-shock scattering giving a blueshift of $V_s/2$. Multiple scatters and some diffusion in frequency still takes place within the H I columns on either side of the shock front after each shock crossing. However, the velocity shift incurred by this frequency diffusion is very small compared to the huge blueshift obtained in just a single shock front crossing. Thus, the gas velocity discontinuity across the shock front provides the most efficient escape route for resonant Lyα photons, cutting down the millions of 'local' scatterings otherwise necessary in static media for escape far in the damping wings to a comparatively small number of scatters (across the shock front and within the H I columns after each shock crossing).

In our model, the separation between successive peaks gives the shock velocity V_s and must therefore be equal, as is observed. Our fit gives directly a $V_s \approx$ 300 km/s. The bulk (or the maximum) of the Lyα flux emerges at a velocity position proportional to $(N_{HI}\, V_s)^{\frac{1}{3}}$. Larger columns necessitate more across-shock scatters before escape and so result in Lyα emerging in peaks of higher order, farther to the blue. The model shown here implies an H I column for each of the two scattering layers of $N_{HI} = 1.3\ 10^{21}$ cm^{-2}. One layer is associated with the preshock gas ahead of the shock and the other is associated with the recombined gas shell in the trailing postshock gas.

4. A Powerful Jet Induced Starburst in 1243+036?

Using a different slit orientation, Van Ojik et al. (1996) report that the blue excess Lyα flux is displaced spatially from the nucleus and coincides with the radio jet bend seen in their radio maps 2″ south-east of the nucleus. Such a radio bend confirms the existence of a shock while its spatial association with Lyα only adds to the plausibility of the Fermi acceleration model. But what is the ultimate source of the Lyα photons which are blueshifted across the shock front? It cannot be the shock itself as this would imply absurdly high densities to account for the observed Lyα luminosity ($\sim 10^{43.4}$ erg/s). It cannot be nuclear photoionisation since the existence of *two* neutral gas mirrors bracketing the accelerated Lyα photons is essential to the Fermi acceleration process; nuclear photoionisation would prevent the trailing H I mirror from existing. The most plausible explanation remaining is that of a colossal jet-induced starburst, similar in nature to that envisaged by Rees (1989). Moreover, the non-detection of C IV emission in 1243+036 argues against nuclear photoionisation or shock excitation and favours the starburst picture. Interestingly, the ubiquitous C IV line has also been reported missing in 3C326.1, another radio galaxy with asymmetric Lyα to which Neufeld and McKee (1988) applied their novel Fermi acceleration model. It may be that blue asymmetric Lyα profiles are a sign of extranuclear starbursts. Adopting a Salpeter initial mass function of slope 1.35 which extends from 0.1 to 125 $M_\odot$, we derive a luminosity for the hot stars of $1.3\ 10^{54}$ ionising photons/s from the observed Lyα luminosity. Assuming an instantaneous burst of star formation with this initial mass function gives a mass of newly formed stars of $\geq 5\ 10^7\ M_\odot$ (Bruzual and Chariot, 1996).

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Photos from Science Writers' Symposium

On the occasion of the VLT UT1 First-Light Event, a Science Writers' Symposium took place on Monday, April 27, and Tuesday, April 28, 1998, at the ESO Headquarters (Garching, Germany) with a complete briefing for media representatives about the VLT Project (technology, science) and its continuation after the UT1 First Light. The presentations were mostly made by ESO technical and scientific staff. About 40 media representatives participated, from all ESO member countries and beyond.

The ESO Director General, Prof. Riccardo Giacconi, introduces the VLT and its many scientific and organisational aspects. ▶

The participants enjoy the teleconference with Paranal.

Massimo Tarenghi during the teleconference with Paranal. On the other side, at Paranal, Jason Spyromilio and Peter Gray.