Highly Variable Apparent Speed in the Quasar 3C 279

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Observations:

We have obtained total intensity images of 3C 279 with the VLBA at 7 mm in 1995-1997 at 7 epochs (Jorstad et al. 2001)

We have performed total and polarized intensity imaging of 3C 279 bimonthly from March 1998 to April 2001 at 7mm with the VLBA (Jorstad et al. 2004)

We have been monitoring the VLBI structure of 3C 279 in total and polarized intensity monthly from April 2001 until the present at 7mm with the VLBA
\[ \Omega_M = 0.3 \quad \Omega_{\Lambda} = 0.7 \]

\[ H_0 = 70 \text{ km s}^{-1}\text{Mpc}^{-1} \]

Apparent Speed

C8: \( \beta_{\text{app}} = 5.5c \rightarrow 13c \)

C10: \( \beta_{\text{app}} = (2.1 \pm 0.6)c \)

C11: \( \beta_{\text{app}} = (3.8 \pm 0.8)c \)

Agudo et al. 2001

Unwin et al. 1979:

\( \beta_{\text{app}} = (2.2 \pm 0.4)c \)
Apparent Speed

C8: $\beta_{\text{app}} = (5.9 \pm 0.4)c$
$T_0 = 1995.74 \pm 0.03$
Wehrle et al. 2001

Jorstad et al. 2001

C9: $\beta_{\text{app}} = (12.8 \pm 0.3)c$
$T_0 = 1996.87 \pm 0.22$

C10: $\beta_{\text{app}} = (11.1 \pm 0.6)c$
$T_0 = 1997.20 \pm 0.23$

C11: $\beta_{\text{app}} = (10.1 \pm 1.9)c$
$T_0 = 1997.58 \pm 0.11$

C12: $\beta_{\text{app}} = (14.8 \pm 1.2)c$
$T_0 = 1998.46 \pm 0.05$

C13: $\beta_{\text{app}} = (14.9 \pm 1.2)c$
$T_0 = 1998.92 \pm 0.03$

C14: $\beta_{\text{app}} = (18.2 \pm 1.0)c$
$T_0 = 1999.50 \pm 0.10$

C15: $\beta_{\text{app}} = (17.2 \pm 0.9)c$
$T_0 = 1999.84 \pm 0.09$

C16: $\beta_{\text{app}} = (15.7 \pm 1.0)c$
$T_0 = 2000.22 \pm 0.17$

C17: $\beta_{\text{app}} = (15.2 \pm 1.0)c$
$T_0 = 2001.00 \pm 0.11$

C18: $\beta_{\text{app}} = (17.4 \pm 1.7)c$
$T_0 = 2002.13 \pm 0.13$

Projected Position Angle

C8: $\Theta = (-131 \pm 2)^\circ$

C9: $\Theta = (-136 \pm 4)^\circ$

C10: $\Theta = (-137 \pm 5)^\circ$

C11: $\Theta = (-135 \pm 4)^\circ$

C12: $\Theta = (-131 \pm 3)^\circ$

C13: $\Theta = (-132 \pm 4)^\circ$

C14: $\Theta = (-138 \pm 4)^\circ$

C15: $\Theta = (-139 \pm 4)^\circ$

C16: $\Theta = (-143 \pm 5)^\circ$

C17: $\Theta = (-137 \pm 7)^\circ$

C18: $\Theta = (-153 \pm 9)^\circ$
\[ \Delta t_{\text{var}} = \delta t / \log \left( S_{\text{max}} / S_{\text{min}} \right) \]
Burbidge, Jones, & O'Dell 1974

\[ \beta_{\text{app}} = \beta \sin \Phi / (1 - \beta \cos \Phi) \]

\[ D = 1 / [\Gamma(1 - \beta \cos \Phi)] \]

<table>
<thead>
<tr>
<th>Doppler Factor</th>
<th>Lorentz Factor</th>
<th>Viewing Angle (°)</th>
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<tbody>
<tr>
<td>C8: D=48</td>
<td>C8: ( \Gamma = 24 )</td>
<td>C8: ( \Phi = 0.3 )</td>
</tr>
<tr>
<td>C9: D=35</td>
<td>C9: ( \Gamma = 20 )</td>
<td>C9: ( \Phi = 1.1 )</td>
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<tr>
<td>C10: D=22</td>
<td>C10: ( \Gamma = 14 )</td>
<td>C10: ( \Phi = 2.1 )</td>
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<tr>
<td>C11: D=21</td>
<td>C11: ( \Gamma = 13 )</td>
<td>C11: ( \Phi = 2.2 )</td>
</tr>
<tr>
<td>C12: D=20</td>
<td>C12: ( \Gamma = 15 )</td>
<td>C12: ( \Phi = 2.8 )</td>
</tr>
<tr>
<td>C13: D=18</td>
<td>C13: ( \Gamma = 15 )</td>
<td>C13: ( \Phi = 3.2 )</td>
</tr>
<tr>
<td>C14: D=18</td>
<td>C14: ( \Gamma = 15 )</td>
<td>C14: ( \Phi = 3.2 )</td>
</tr>
<tr>
<td>C15: D=19</td>
<td>C15: ( \Gamma = 18 )</td>
<td>C15: ( \Phi = 3.1 )</td>
</tr>
<tr>
<td>C16: D=21</td>
<td>C16: ( \Gamma = 19 )</td>
<td>C16: ( \Phi = 2.6 )</td>
</tr>
<tr>
<td>C17: D=37</td>
<td>C17: ( \Gamma = 22 )</td>
<td>C17: ( \Phi = 1.1 )</td>
</tr>
<tr>
<td>C18: D=42</td>
<td>C18: ( \Gamma = 25 )</td>
<td>C18: ( \Phi = 1.0 )</td>
</tr>
</tbody>
</table>

\[ D = R s / [c \Delta t_{\text{var}} (1+z)] \]

R=3.1Gpc
z=0.538
s=1.6a
a=FWHM
\[ \Delta t = (130\pm40) \text{ days} \rightarrow \text{Dist} \sim 40 \text{ pc} \]

deprojected, or \( \sim 0.016 \text{ mas projected} \)

Size_{core} \sim 0.03-0.05 \text{ mas} \rightarrow 5-10 \text{ pc}
Conclusions

1. We have detected an increase in the apparent speed inside of 2 mas from the VLBI core from 6c to 18c.
2. The apparent acceleration is accompanied by a change in the projected position angle of the jet "nozzle" from -120° to -160°.
3. We explain these effects as the result of a change in the jet nozzle direction from 0.3° to 3.2° relative to the line of sight while the Lorentz factor of the jet flow experiences modest variations, \( \Gamma = 20 \pm 5 \).
4. The total intensity light curve at 37 GHz varies simultaneously with the VLBI core light curve at 43~GHz. The X-ray variations lead the radio variations at 37~GHz by 130±40 days. This implies that the X-ray emission region is 0.016 mas upstream of the VLBI radio core observed at 43 GHz and may coincide with the "true" core of the jet.
5. Highly relativistic perturbations create stationary features behind the main disturbance with average lifetime \( \sim 0.5 \text{ yr} \).