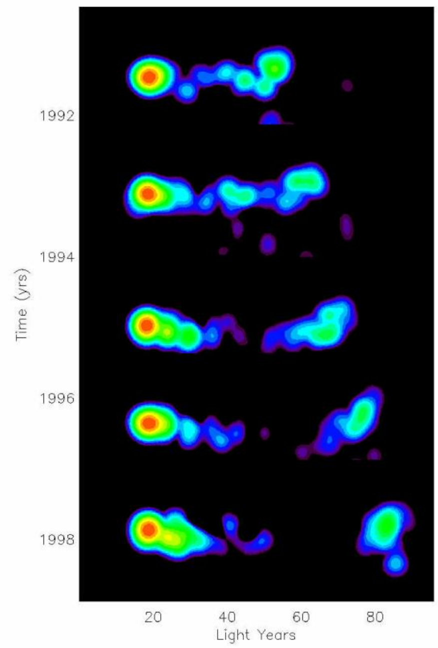
Superluminal motion of Radio Jets



Apparent Superluminal Motion in 3C279

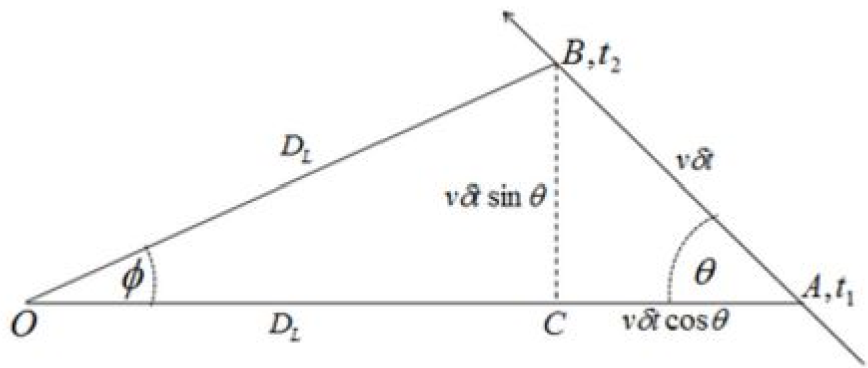
- Above figure shows motion of jet in quasar 3S279 in Radio taken over 7 years.These five images are part of a larger set of twenty-eight images made with the VLBA and other radio telescopes from 1991 to 1997 to study the detailed properties of this energetic quasar.The bright red spot to the left is the stationary core.The motion of the rightmost blue blob shows that the blob moved about 25 light years from 1991 to 1998.Thus,

$$v = \frac{25 \times c}{7} km/s$$

$$\Rightarrow v = 3.57c \Rightarrow v > c$$

  Hence the changes appear to be faster than the speed of light or 'superluminal'.The motion is not really faster than light,the measured speed is due to light-travel-time effects for a source moving near the speed of light almost directly toward the observer.

- **Derivation-**A relativistic jet coming out from center of an AGN with velocity v,the position of the observer is at O.
  At time t_1 a light ray from the jet leaves the jet,another ray leaves the jet from point B at t_2 towards O.These rays are detected at time t'_1 and t'_2 respectively at O.Angle between the line of sight and motion of the jet is θ.This is depicted in the below figure.



$AB = v\delta t$
$AC = v\delta t cos\theta$
$BC = v\delta t sin\theta$
$t_2 - t_1 = \delta t$
$t_1' = t_1 + \frac{D_L + v\delta t cos\theta}{c}$
$t_2' = t_2 + \frac{D_L}{c}$

$$v_{apparent} = \frac{v\delta t sin\theta}{t_2' - t_1'}$$

$$v_{apparent} = \frac{v\delta t sin\theta}{\delta t(1 - \frac{v cos\theta}{c})}$$

Let, $\beta = \frac{v}{c}$
Apparent transverse velocity in direction CB,

$$\beta_T = \frac{(v/c) sin\theta}{(1 - cos\theta \frac{v}{c})}$$

$$\beta_T = \frac{\beta sin\theta}{1 - \beta cos\theta}$$

- The apparent transverse velocity is maximum for angle $(0 < \beta < 1)$,

$\frac{\delta\beta_T}{\delta\theta} = \frac{\delta}{\delta\theta}[\frac{\beta sin\theta}{1 - \beta cos\theta}]$
$\frac{\delta\beta_T}{\delta\theta} = \frac{\beta cos\theta}{1 - \beta cos\theta} - \frac{(\beta sin\theta)^2}{(1 - \beta cos\theta)^2} = 0$
$\Rightarrow \beta cos\theta(1 - \beta cos\theta)^2 = (1 - \beta cos\theta)(\beta sin\theta)^2$

Solving the above,

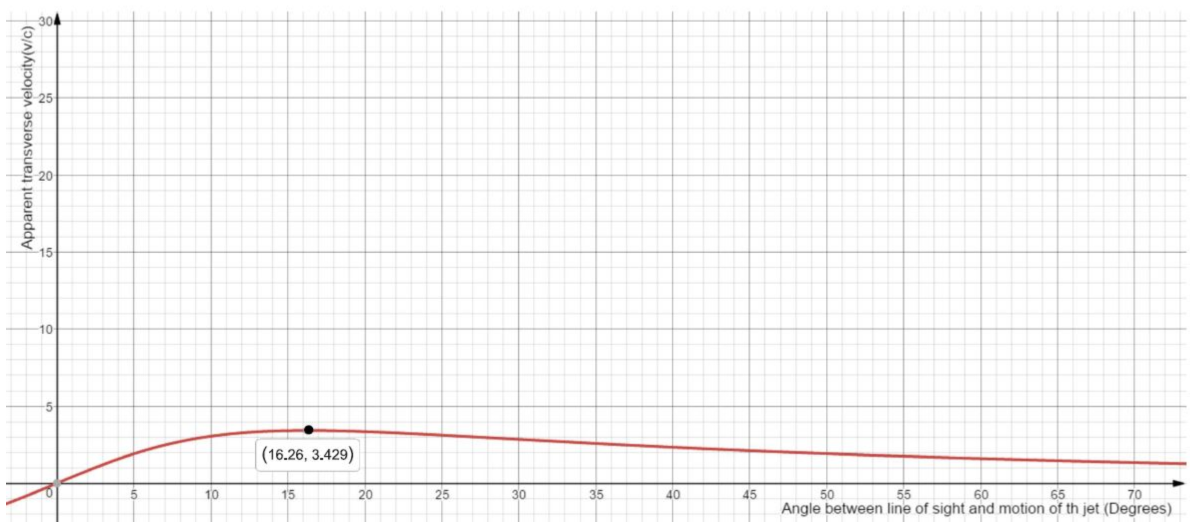
$$cos\theta_{max} = \beta$$

$$\Rightarrow sin\theta_{max} = \sqrt{1-\beta^2} = \frac{1}{\gamma}$$

$$\beta_T^{max} = \frac{\beta\gamma}{1-\beta^2} = \frac{\beta\gamma}{1/\gamma^2} = \beta\gamma$$

$\beta_T^{max} = \beta\gamma$
β_T^{max}can be greater than β.

- In the above image of jet from 3C279,the blue-green blob is part of a jet pointing within 2 degrees to our line of sight, and moving at a true speed of 0.997 times the speed of light. For a value of $\gamma = 0.96$, the plot of β_T vs θ,



Above plot is plotted for θ vs β,the maximum apparent transverse velocity is observed at $\theta = 16.26^o$