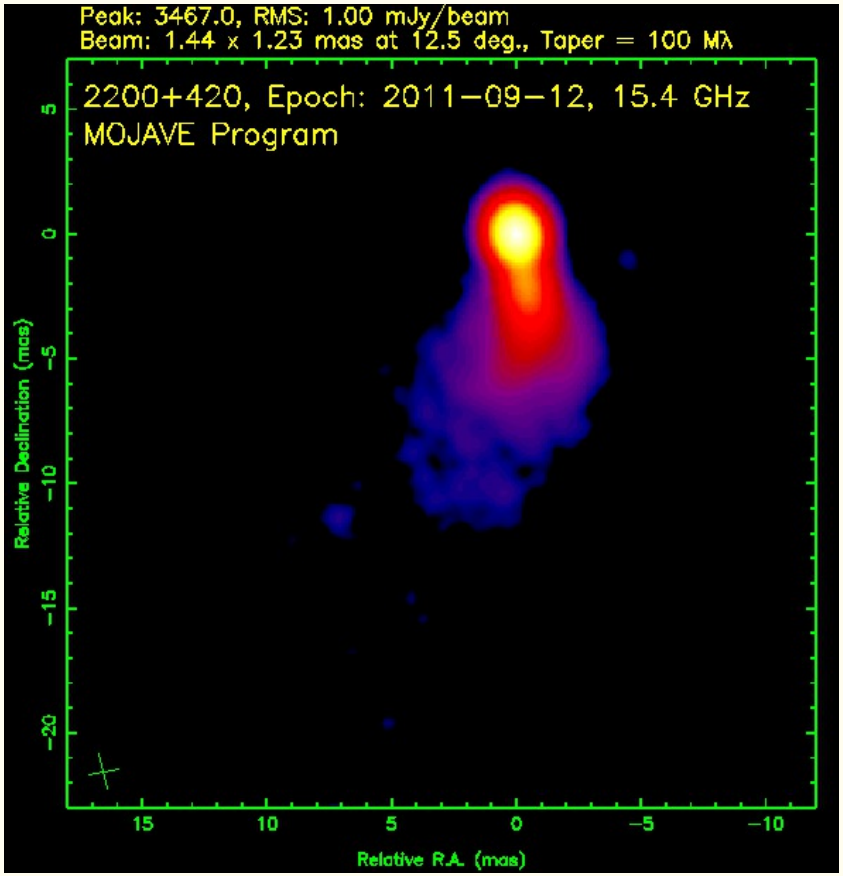
Recollimation Shock, Transverse Waves and the Whip in BL Lacertae

M.H. Cohen
Caltech



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- D. Meier (JPL)
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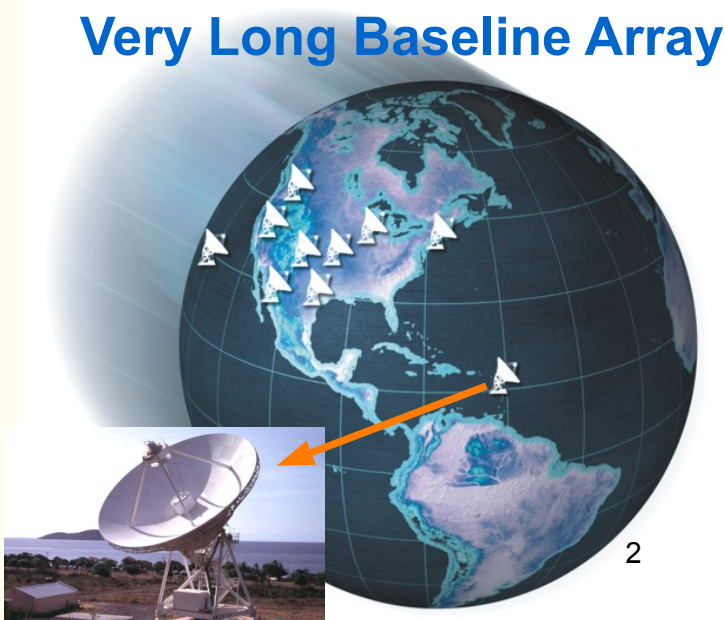
- E. Ros (Valencia, Spain)

Monitoring
Of
Jets in
Active Galaxies with
VLBA
Experiments



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BL Lac Topics

- Components, Ridge Line
- Recollimation Shock
- PA Variations: Wobble
- Transverse Waves
- Wave Speeds
- Relaxation in 2010: Wiggle
- Conclusions

Components

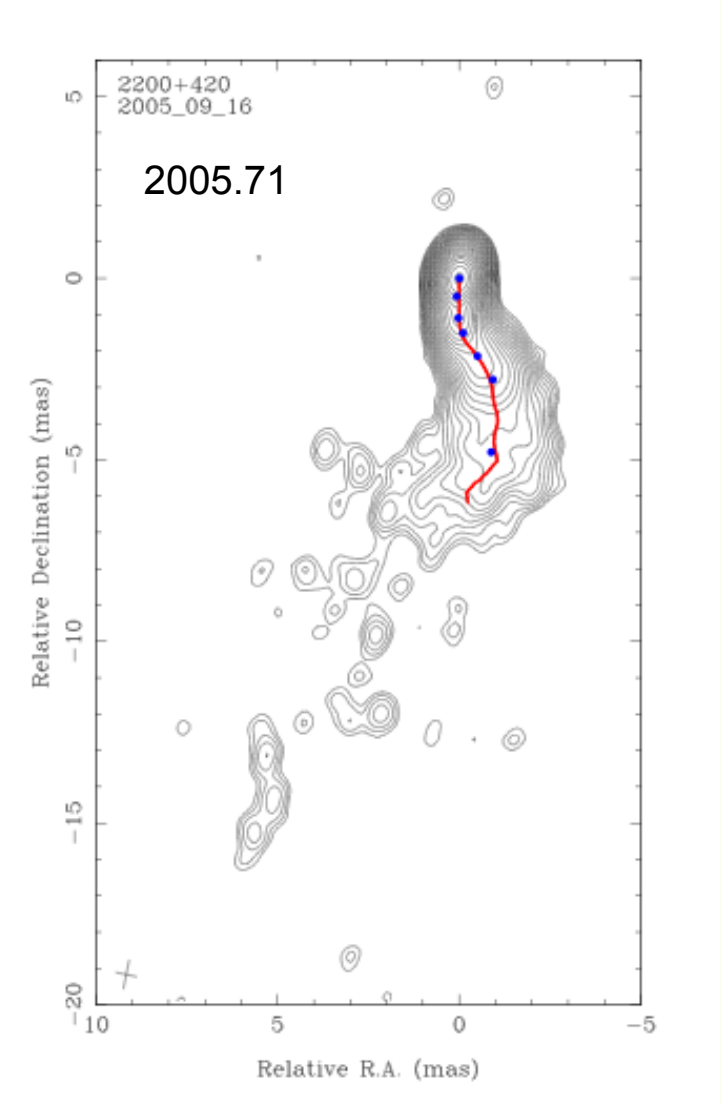
- Components are a small number of elliptical Gaussians that sum to the image. They usually are circular.
- A component is often a bright spot in the image.
- Components are tracked in time, if the cadence of observations is fast enough.

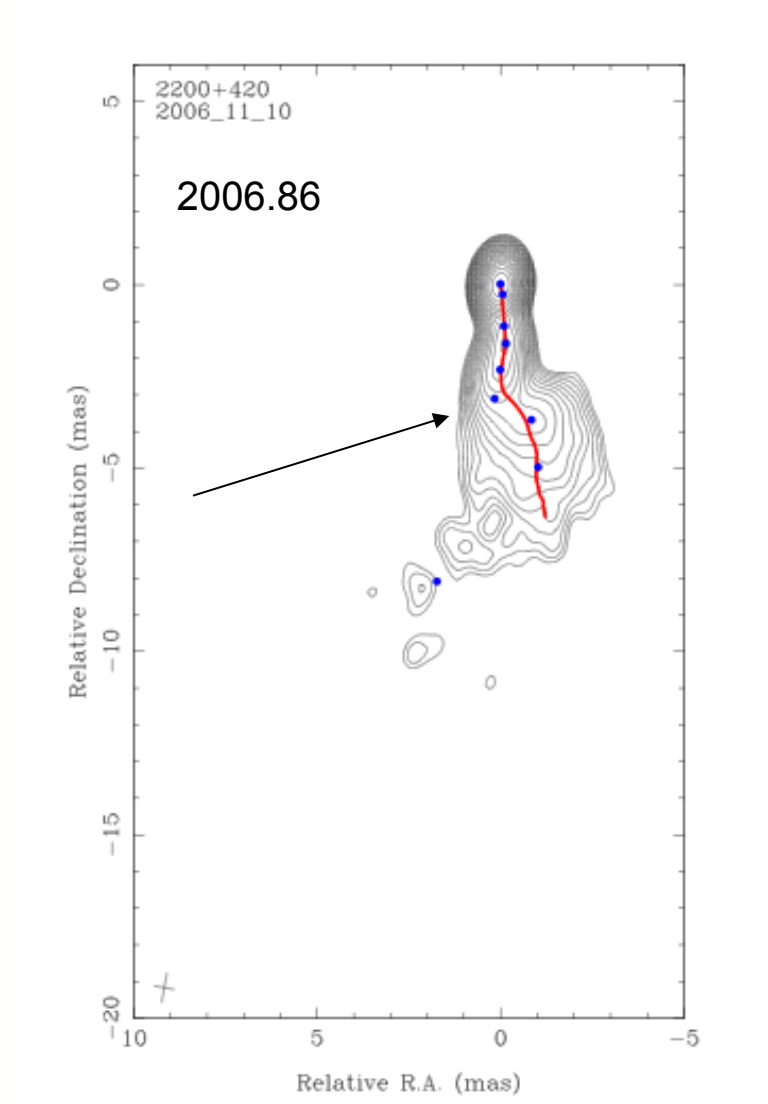
Ridge Line

- BL Lac is elongated and has a ridge.

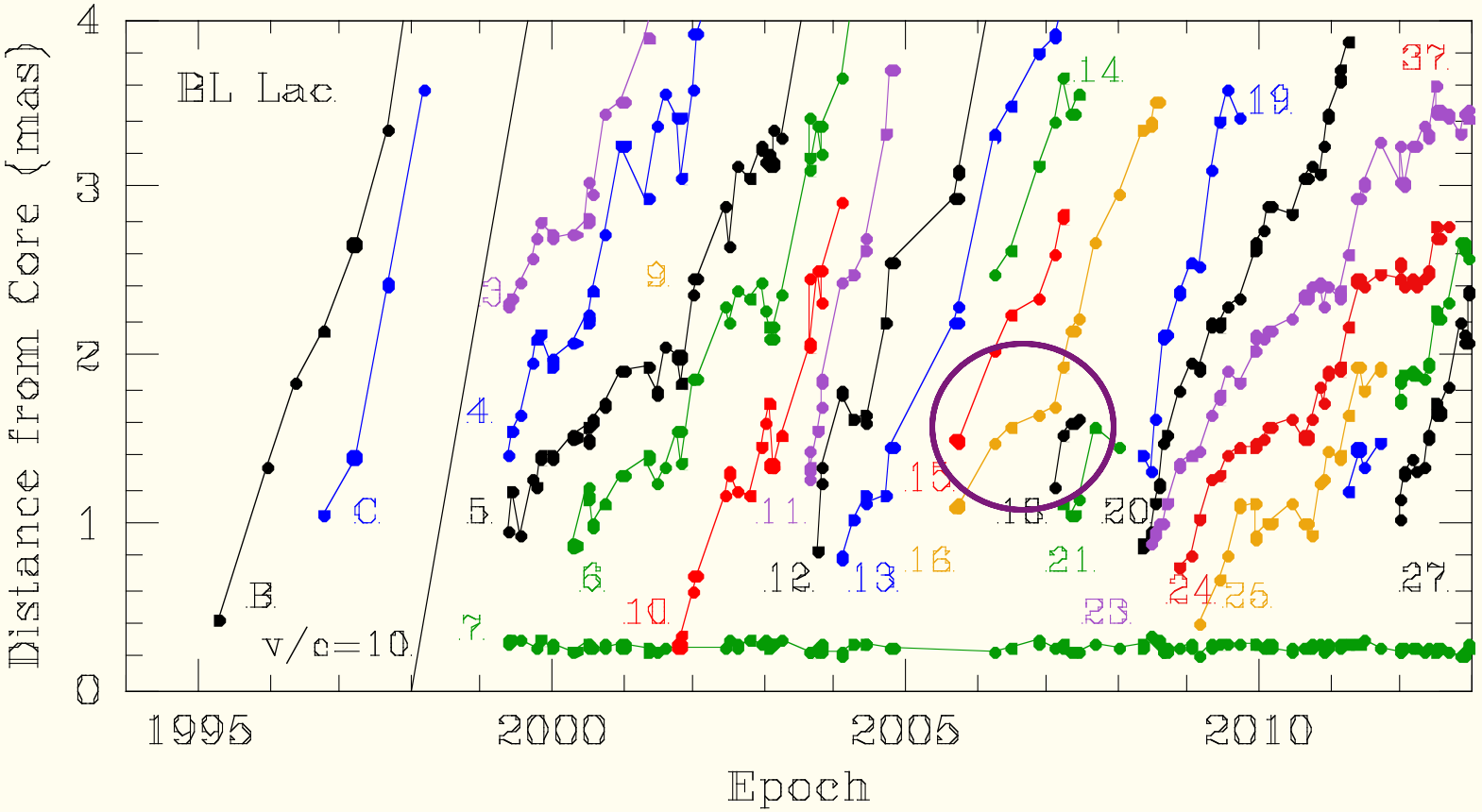
- Most components move downstream
- along the ridge (±0.1 mas)

Ridge Line and Components



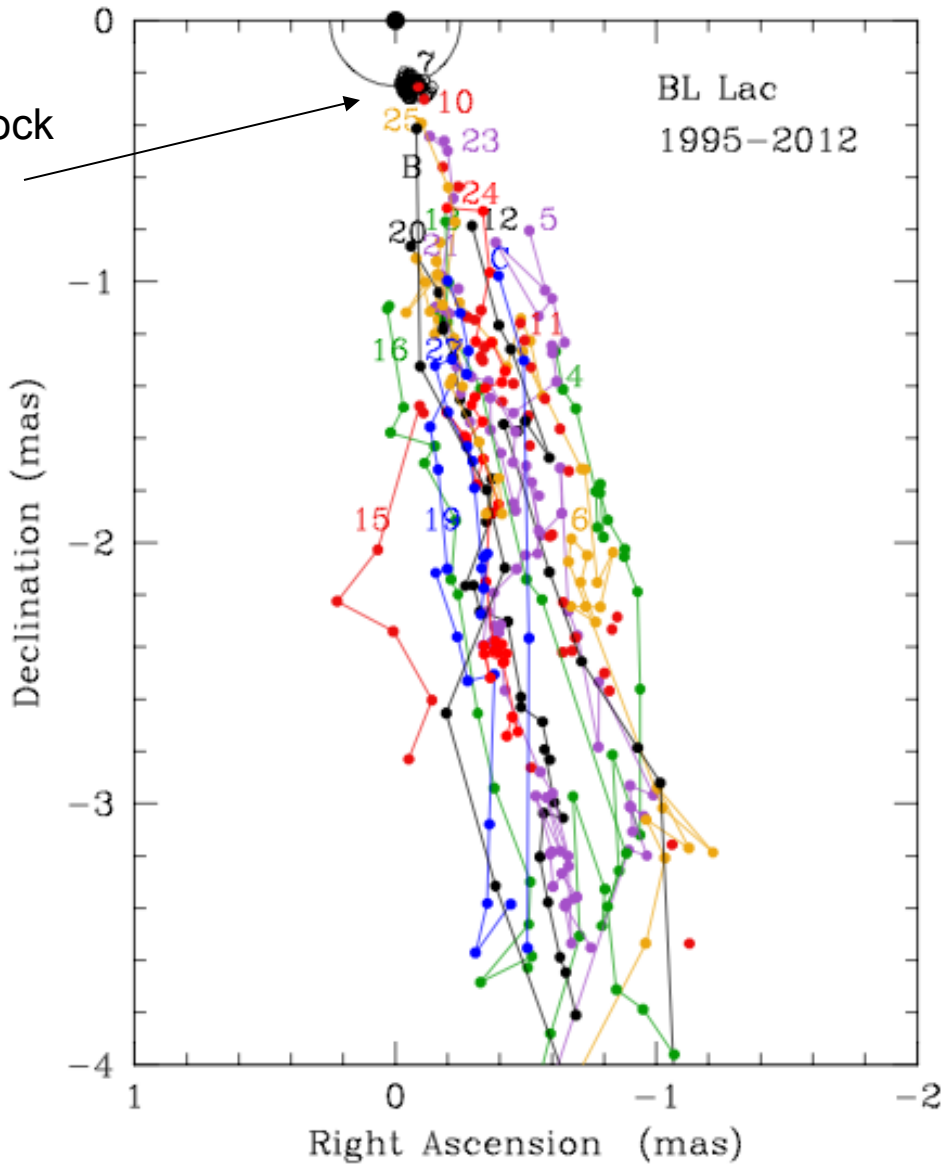


Several New Components per Year
Max Speed 10.6c



BL Lac Component Tracks

quasi-stationary
recollimation shock



Recollimation Shock

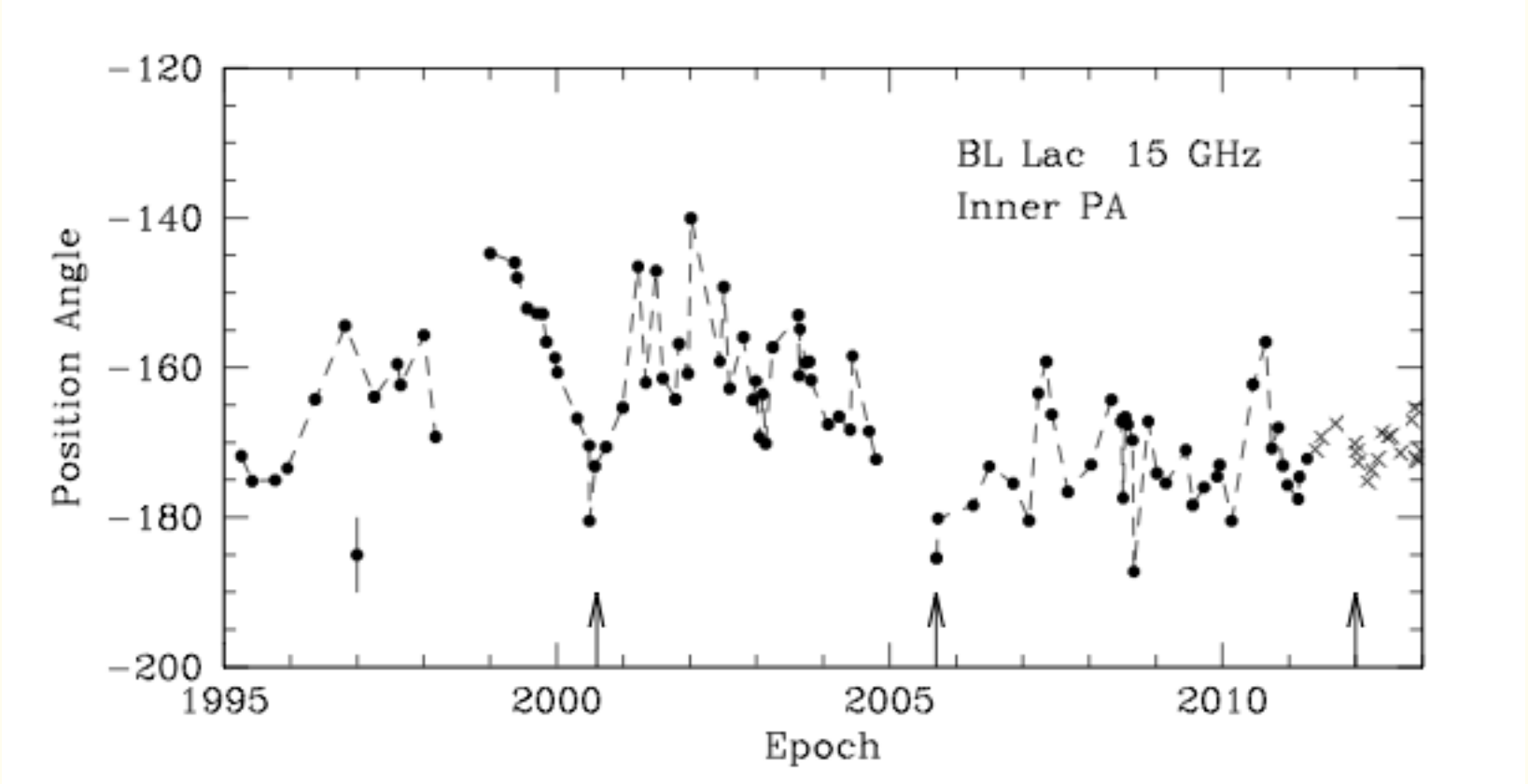
- Component 7 = recollimation shock
- Analogy to M87, 3C120
- Simulation (Lind et al 1999, ...) shows a ‘magnetic chamber’ and fast cpts ejected into a ‘nose cone’ (not full 3D RMHD) (Meier p715)
- Need strong toroidal component in the magnetic field

Recollimation Shock II

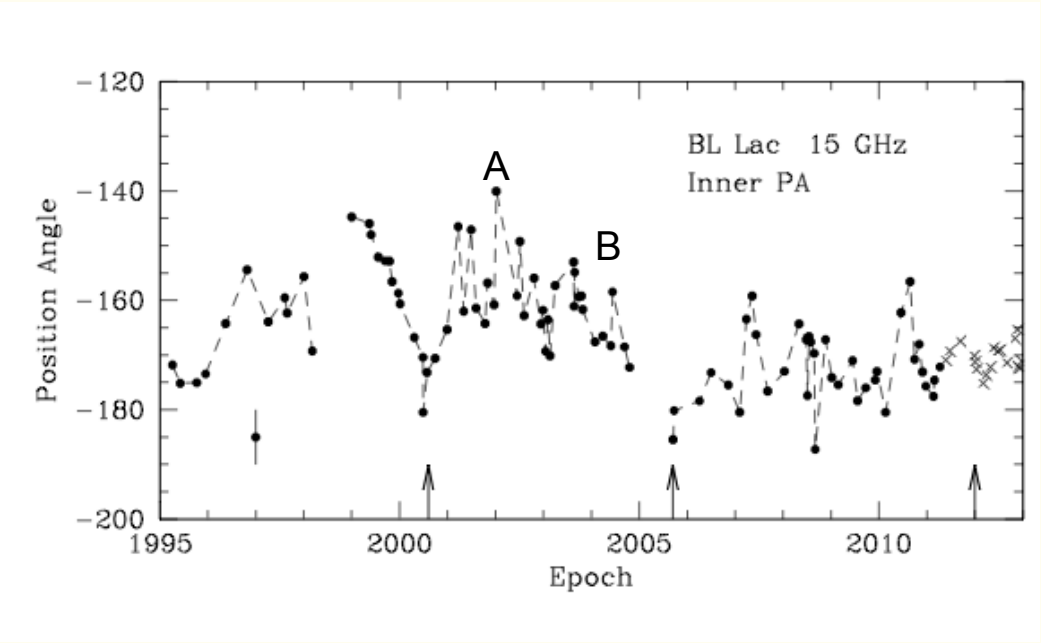
	z	vmax	dist from core
• 3C 120	0.033	5.3c	~ 5 mas
		3.1 *	80 mas ~ 3×10^7 r_g
• M 87	.00436	4.3 **	>= 10^6 r_g
• BL Lac	.0686	10.6 #	~ 10^6 r_g

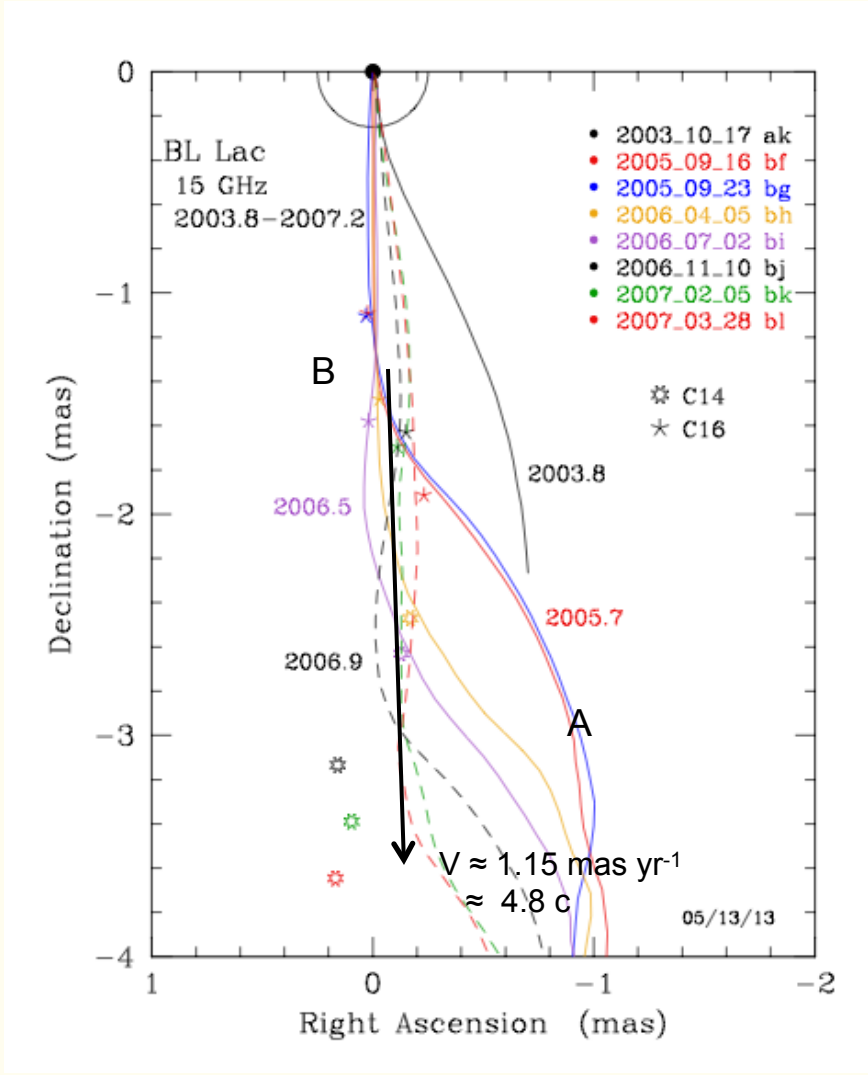
* downstream from C1 Agudo et al 2012
** downstream from HST1 Cheung et al 2007
# downstream from cpt 7 MOJAVE

BL Lac
Position Angle vs Epoch

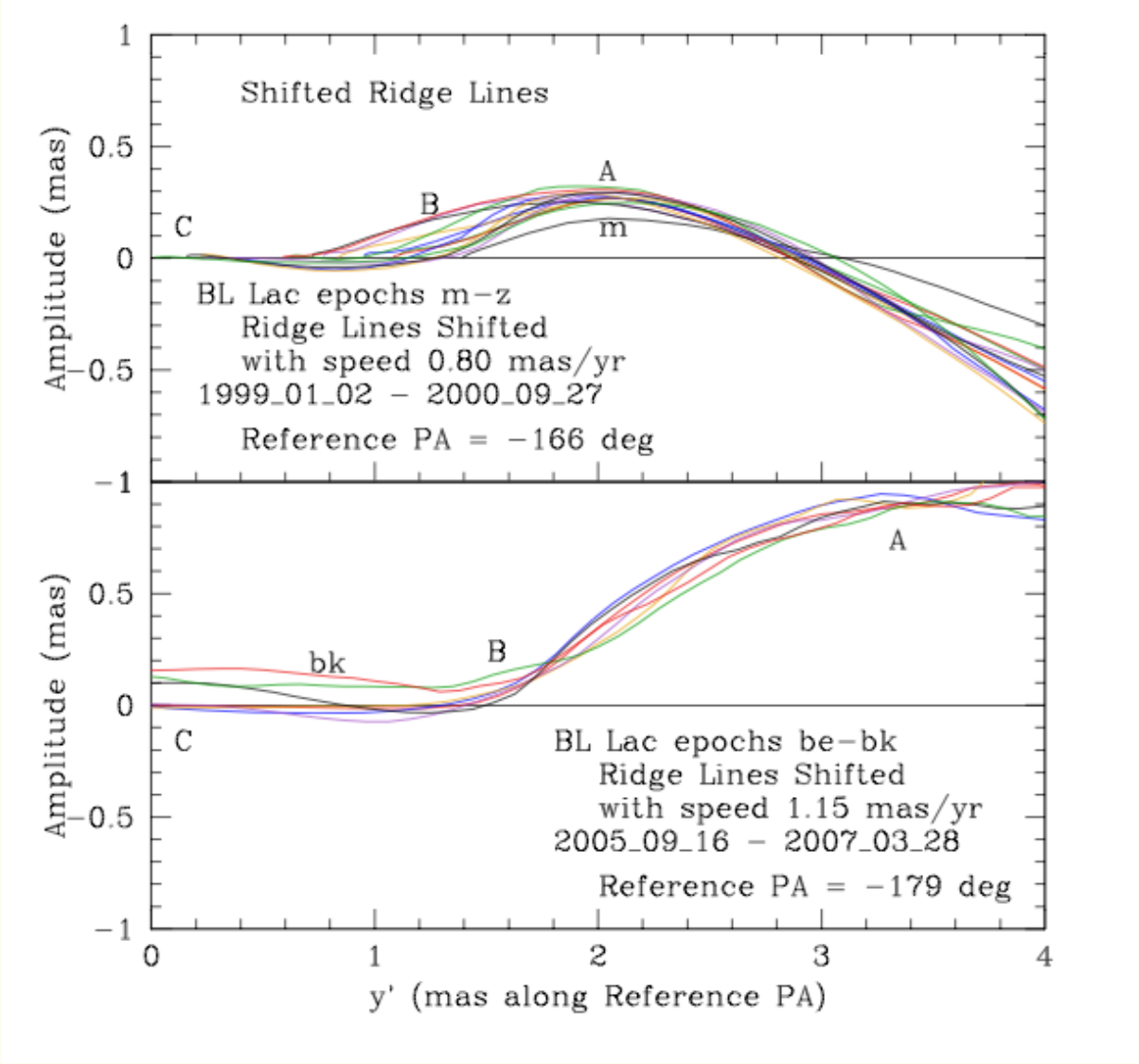


Transverse Wave 2004 - 2007

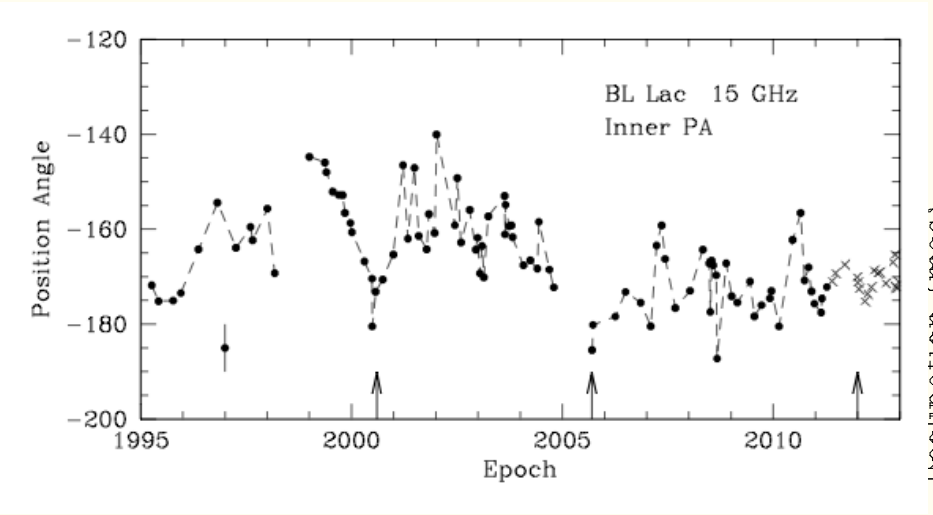


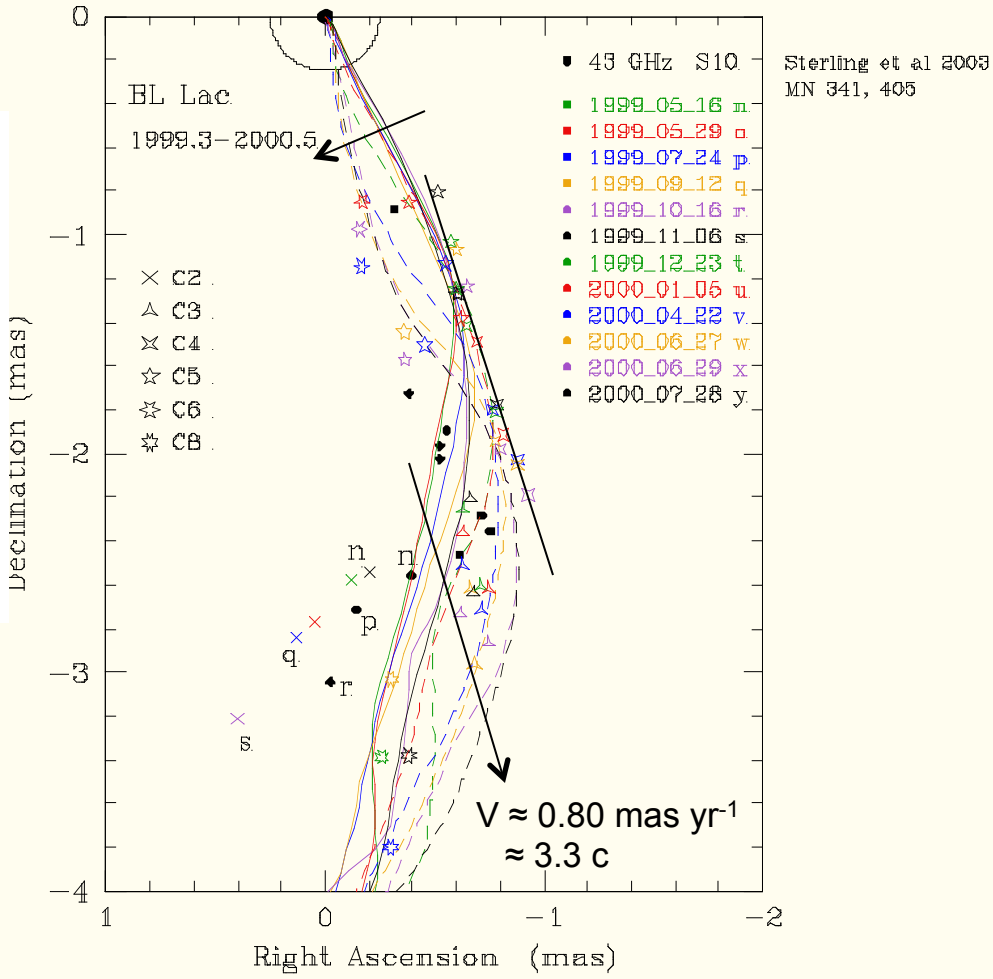


Shifted Ridge Lines



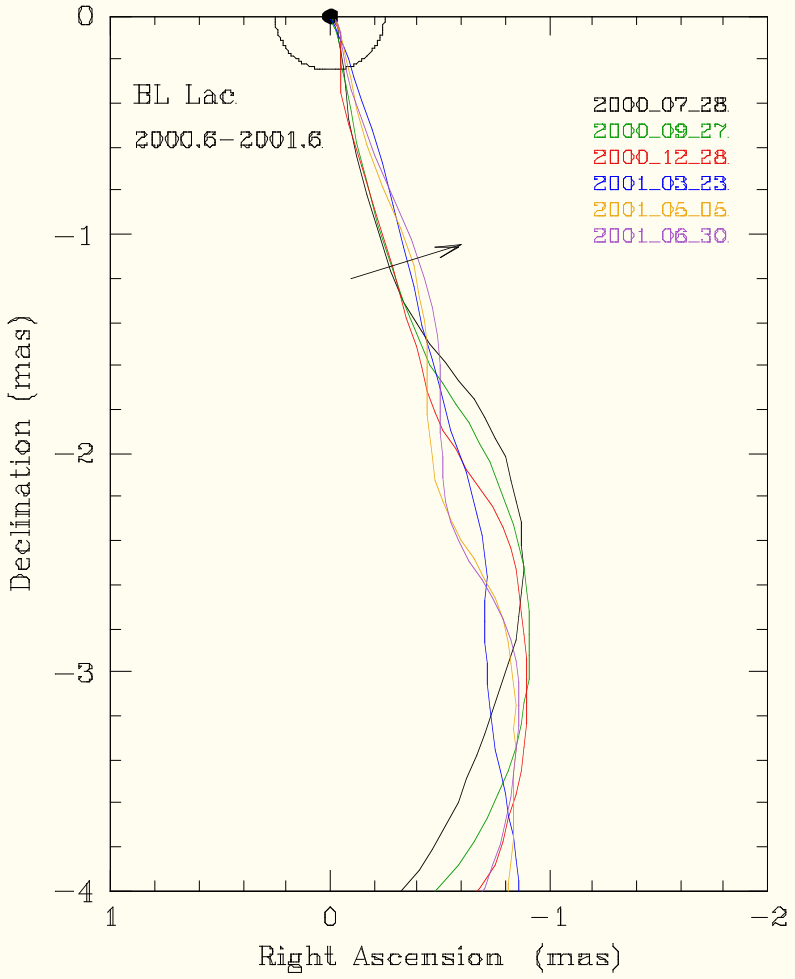
Transverse Waves 1999-2000

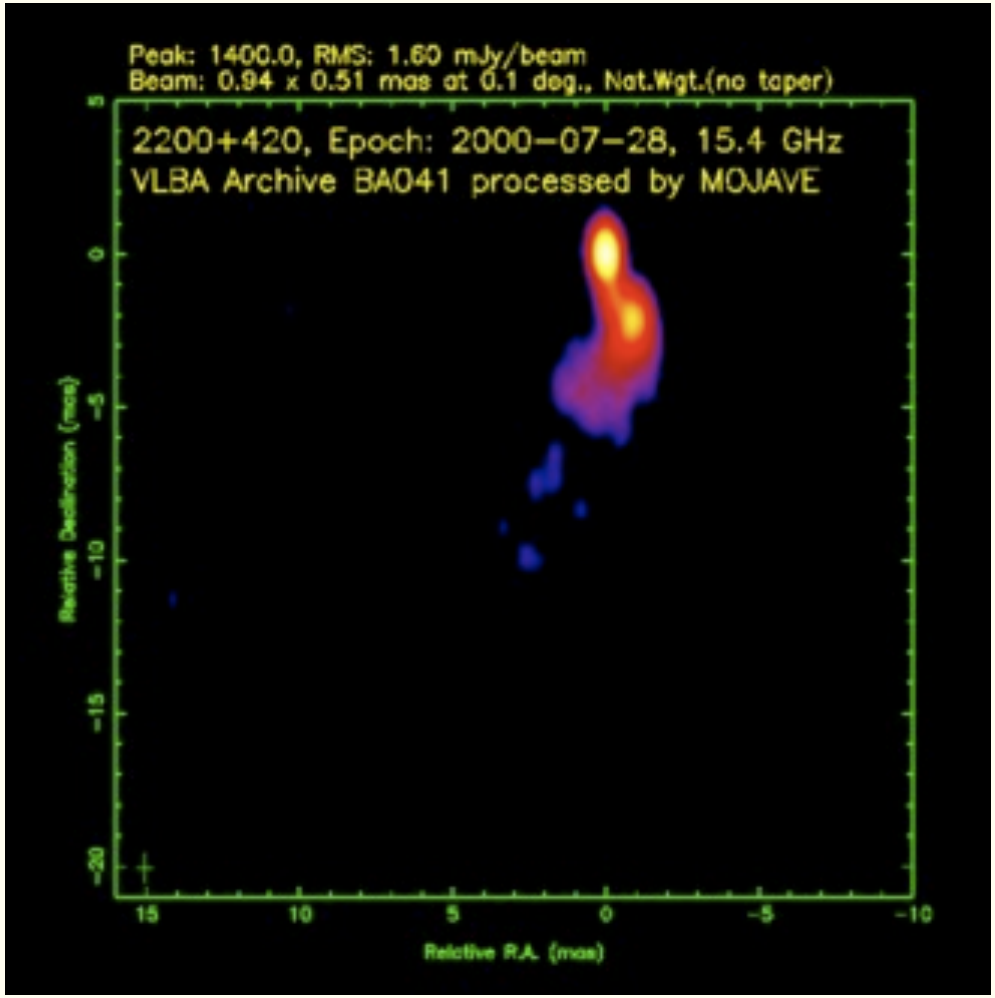




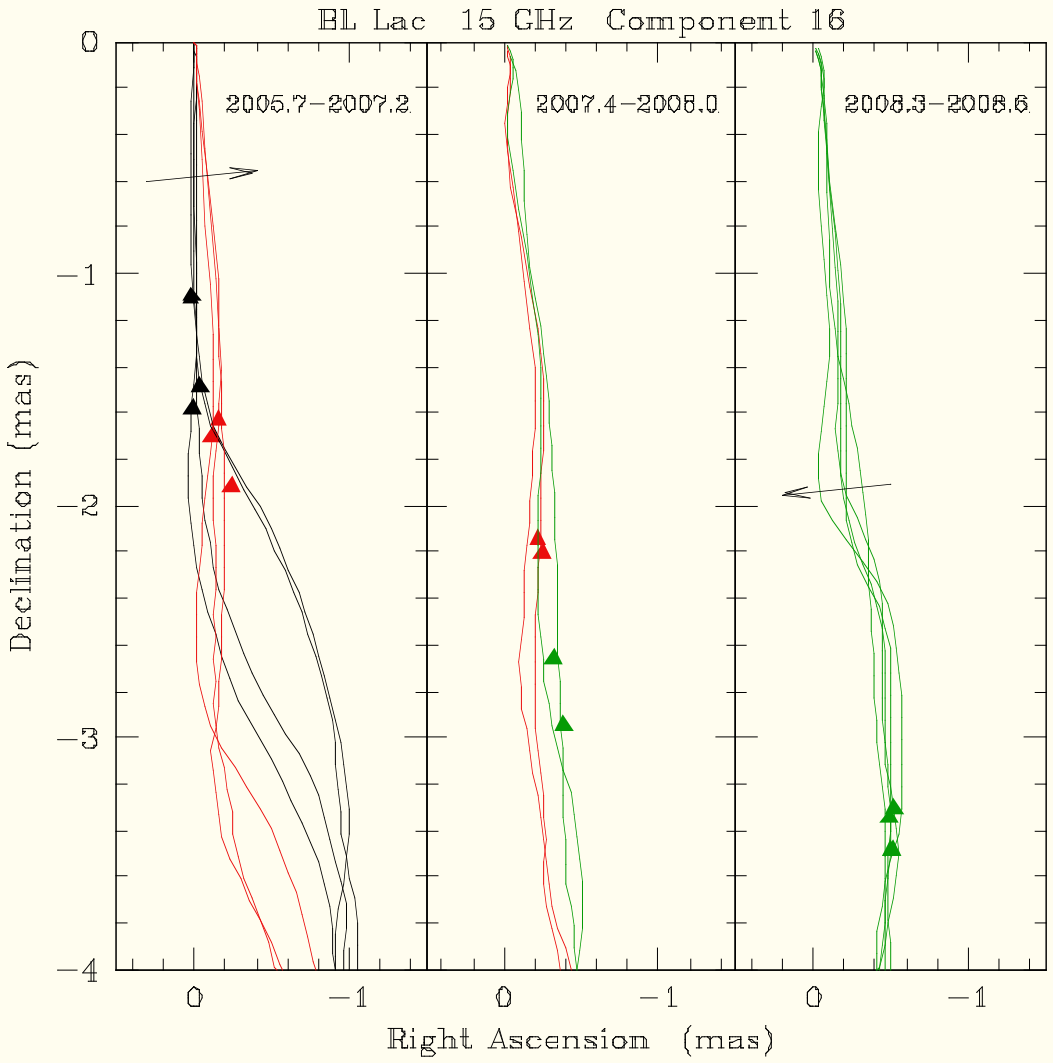
Sterling et al 2003
MN 341, 405

Transverse Wave 2000-2001





Component 16 Advected with the Transverse Wave



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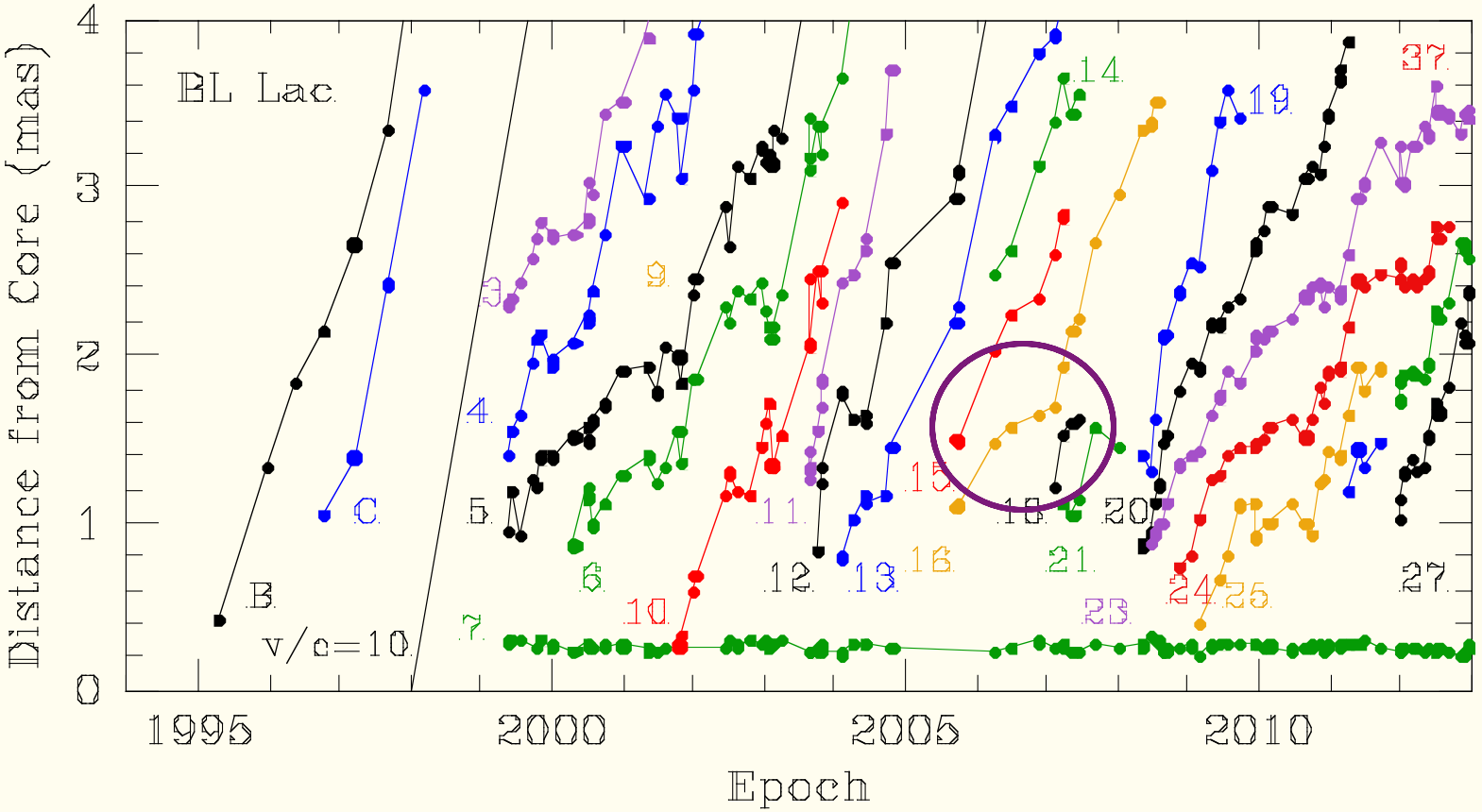

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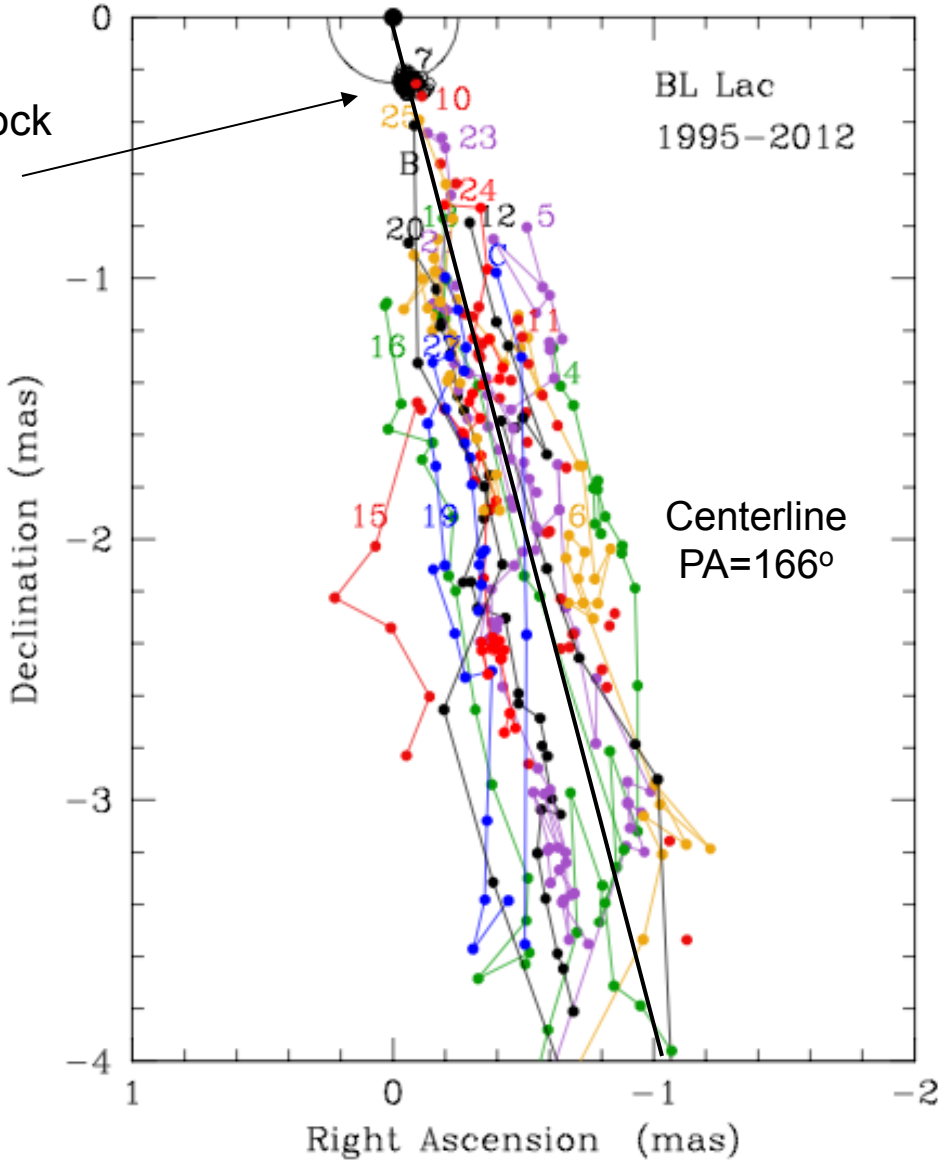
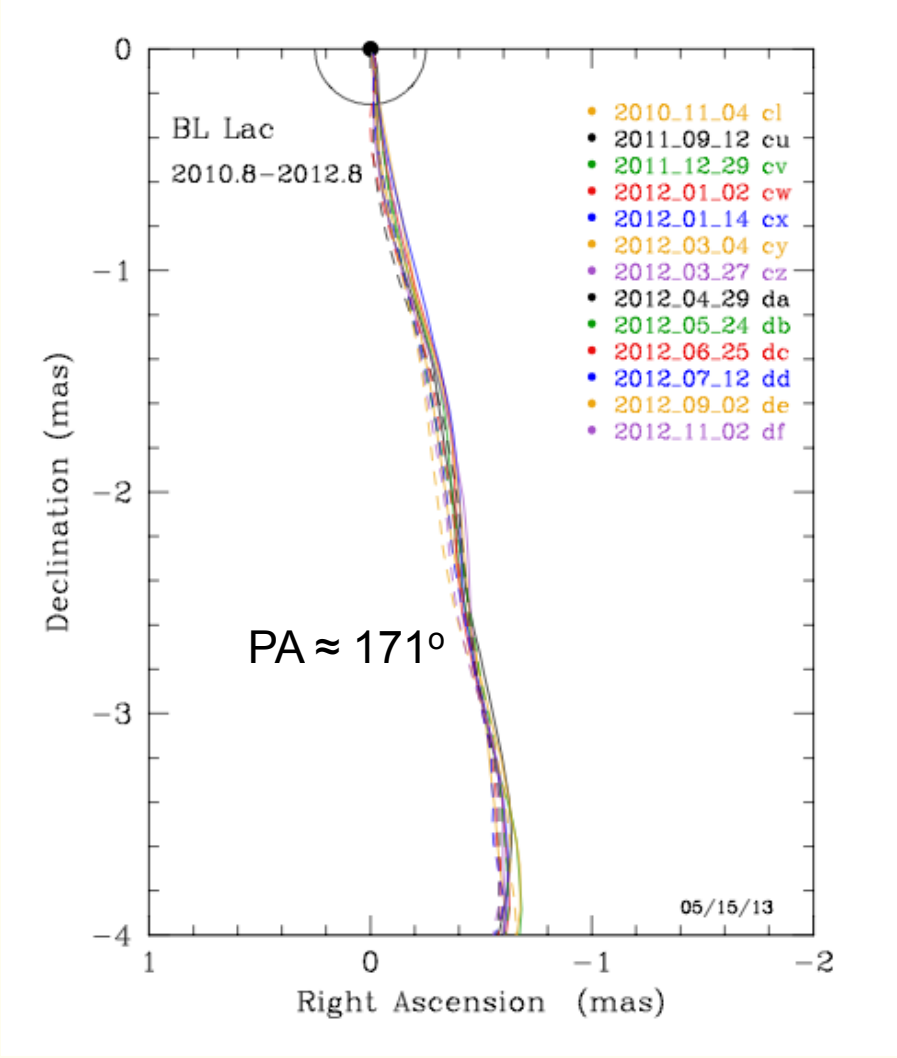
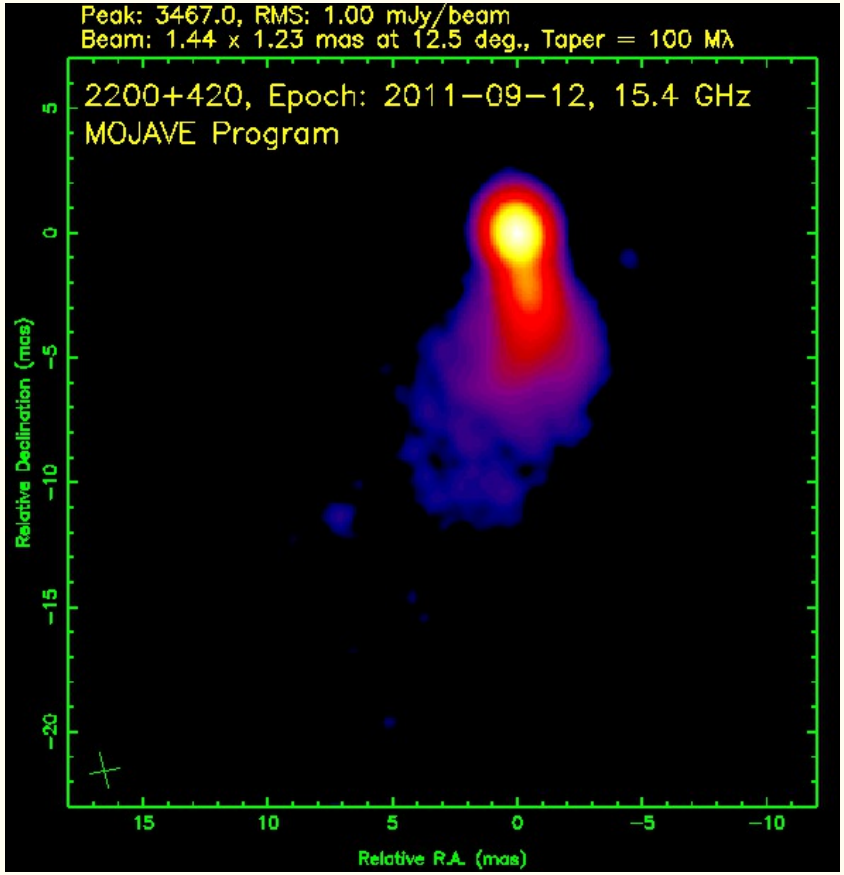


BL Lac 2010.8-2012.8 wiggle





BL Lac
Conclusions I

- Strong quasi-stationary component is identified as a recollimation shock.
- Distance from core ~ 10^6 r_g
- Superluminal components appear to come from or through the recollimation shock.

BL Lac
Conclusions II

- Jet supports transverse waves.
- Waves have superluminal speed.
- Waves are correlated with swings in the inner PA.
- Components are advected with the transverse motion.
- Jet acts more like a rope than a water hose.
- When wave activity dies down, a stable wiggle appears.

Conclusions III

These observations support a model in which the jet contains a strong toroidal magnetic field. Transverse waves (Alfven?) are excited by PA swings of the nozzle, and propagate superluminally downstream, as large-scale wiggles on the ridge line. The superluminal components (fast MHD waves?) stay on the ridge, and can be advected transversely. In 2009 the waves died down, and a small-scale stationary wiggle appeared on the jet.