ENIGMA Lesson 1 ④ Marscher

III. Unconfined Ballistic Jets

If jet plasma's internal energy becomes rest-mass dominated beyond region of main collimation + acceleration, it will maintain ~ constant Γ + constant ψ (cone)

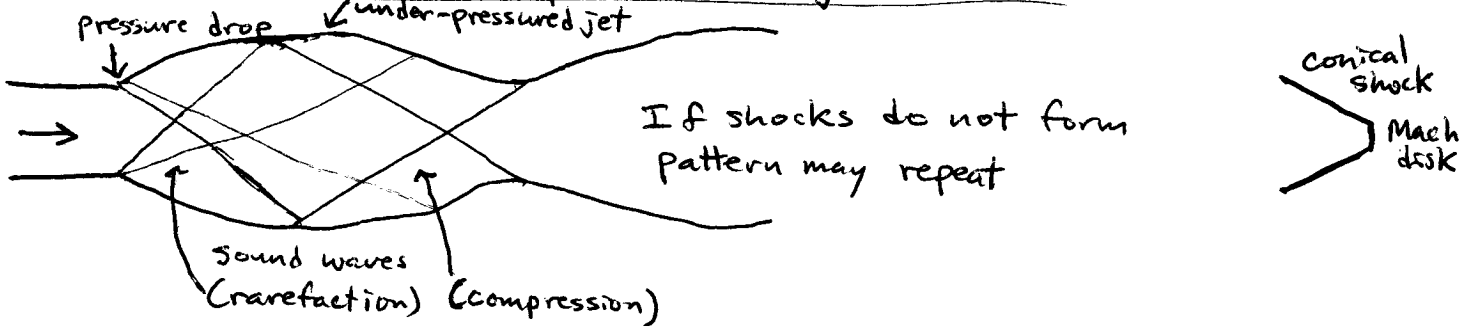
If not rest-mass dominated ($e^- - e^+$ plasma with $\langle\gamma\rangle > 1$), jet will accelerate hydrodynamically

Observed: Jets may accelerate out to pc scales but not beyond

IV. Jets Confined by External Gas Pressure (on Parsec Scales?): 2D + 3D

Blandford-Rees treatment is 1-D
2-D (or 2+D cylindrically symmetric) case is more complex

Consider first idealized scenario: cylindrical, supersonic jet enters a region where confining pressure drops suddenly. The pressure change is transmitted by sound waves that fan out from the point of change:



The jet expands + accelerates, but overexpands because of its inertia
→ pressure drops, jet pressure falls below that of medium, + compression sound waves pinch jet to ~ original radius r

If pressure drop is high enough ($\gtrsim 30\%$?), compression waves steepen to form standing conical shocks
- get similar results in a non-steady jet with no sharp pressure drop

External pressure gradient: similar but each recollimation section is wider than preceding one.

Diverging flow at inlet: conical shocks form in first section usually "Mach disk" transverse shock near axis