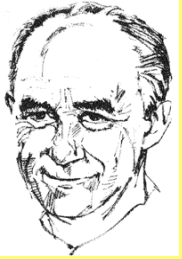
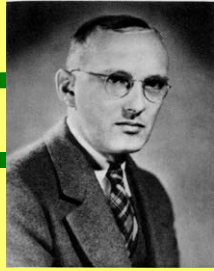


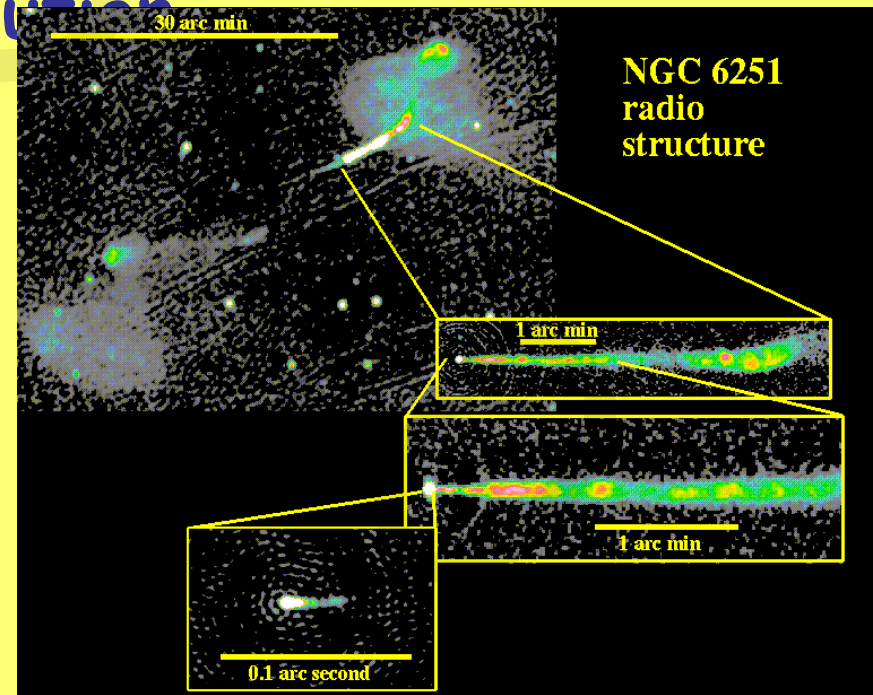


"Observed" Radio and γ-ray emission from Simulated Jets

Roger Blandford
KIPAC, Fermi,Stanford
with help from:
McKinney, Lisanti, Chiang, Scargle, Readhead…

Primary Questions

- Prime Mover?
  - Stars, superstars, supernovae, pulsars… holes
- Black Hole Engineering?
  - Energy flow: disks vs jets
  - Mechanism: (Electro)magnetic vs gas, Accretion vs spin?
- Galaxy Formation and Evolution
  - Mergers
  - AGN vs Starbursts
  - Jets vs winds
  - Feedback…
- Environmental impact
  - (Re-)ionization
  - Cluster evolution…



fm=Jy

Jet-specific Issues

- Anatomical
  - Multi-frequency jet structure
  - Kinematics
  - Composition
- Physiological
  - Emission mechanisms
  - Pressures and powers
  - Confinement
- Sociological
  - Counts, LF, multivariate properties
  - Backgrounds

Jets @Jy +77, fm + 2

- FGST, ACT…OP…Radio, ν all working well
- N~1000 sources sampled hourly-weekly
- Large data volumes justify serious statistical analyses of multi-λ data
  - Irregular sampling, selection effects
  - Work in progress
- Account for Extreme Jets
  - Most variable, fastest, brightest, most polarized
- Modeling must match this increase in sophistication
- Models are now becoming available
  - Understand kinematics, QED, fluid dynamics
  - Ignorant about particle acceleration, transport, radiation, field evolution

Dynamical elements

- Bulk flow
- Shocks
- Shear flow
- Plasmoids. flares, minijets,magnetic rockets…
  - Lorentz boosting
- Precession
  - Disk
  - m=1 instability
- Turbulence

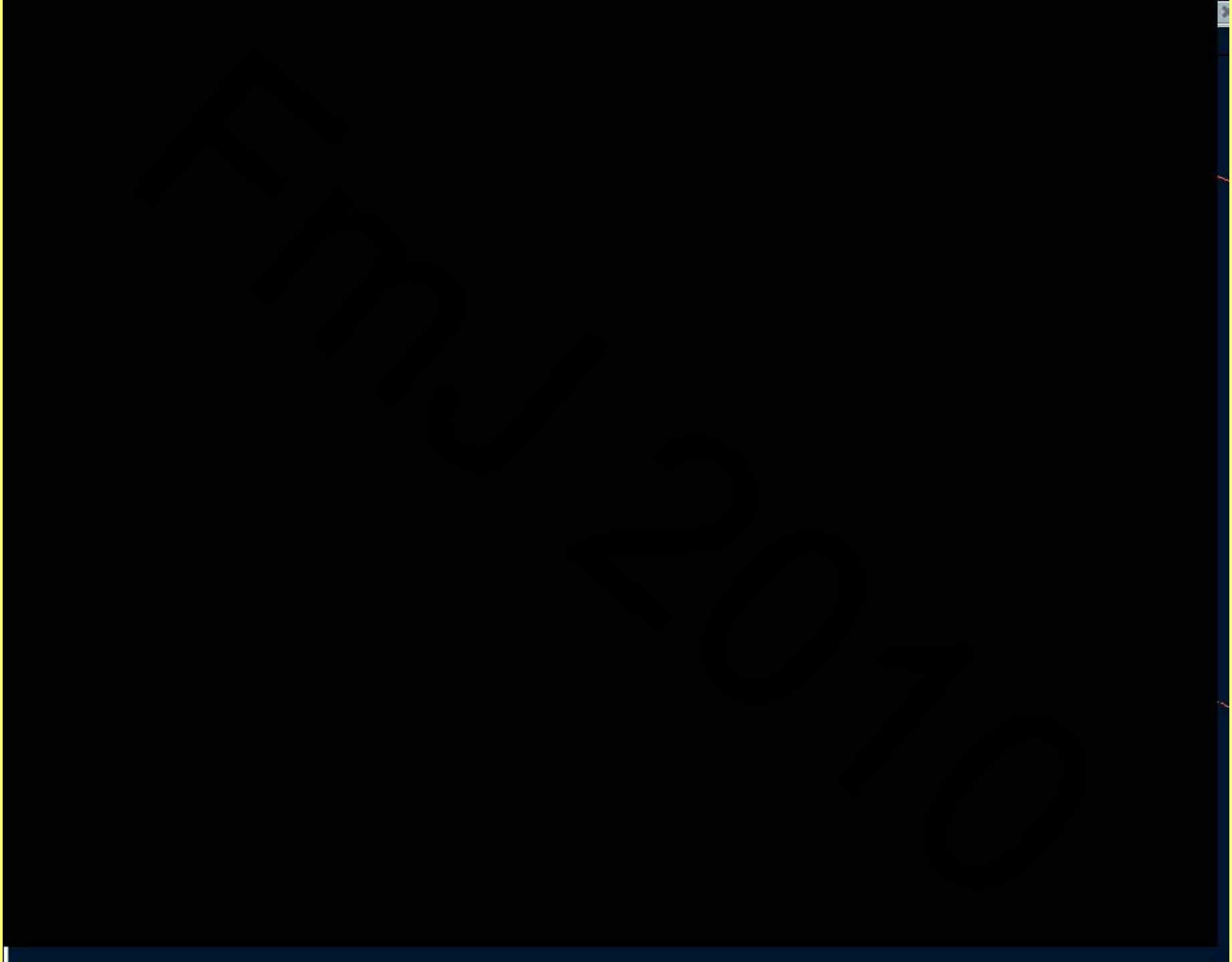
Each of these elements changes the field and the particles

RHD vs RMHD vs RFF

- Fluid – isotropic P, strong shocks, strong acceleration
- RMHD – Anisotropic P, explosive energy release, good Fermi 2
- Force Free – ignore inertial terms, limiting case, no shocks subsonic, strong wave acceleration

Pair vs Ion Plasmas

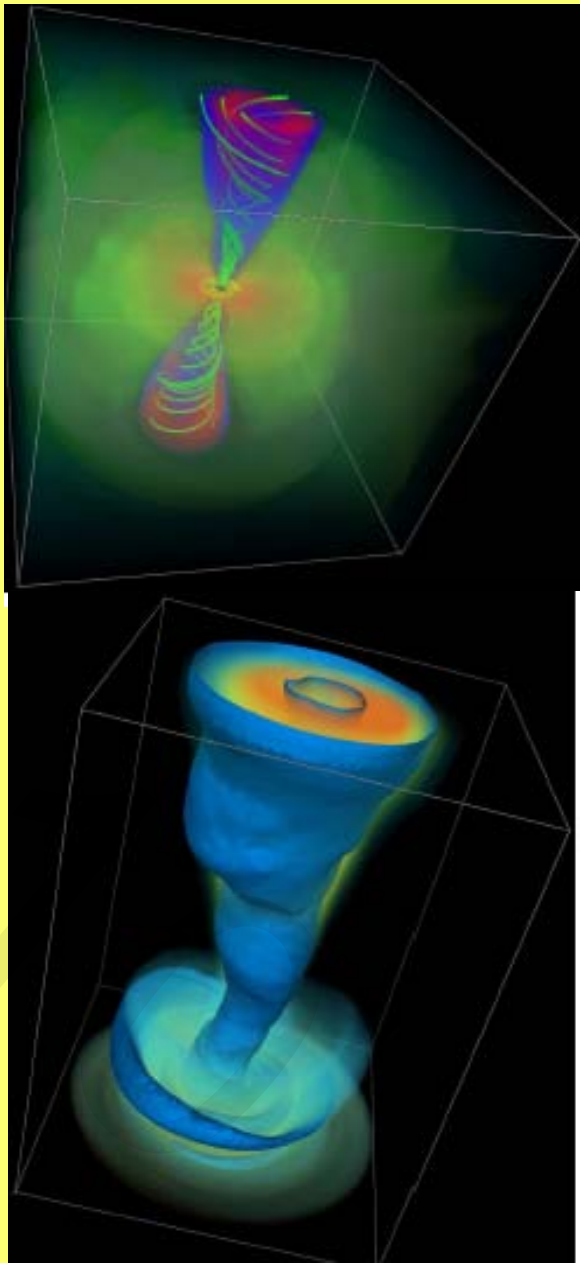
- Pairs must be heavily magnetized to avoid radiative drag
- Circular polarization, Faraday rotation/pulsation
- Expect? Pairs, Field decrease, ions increase

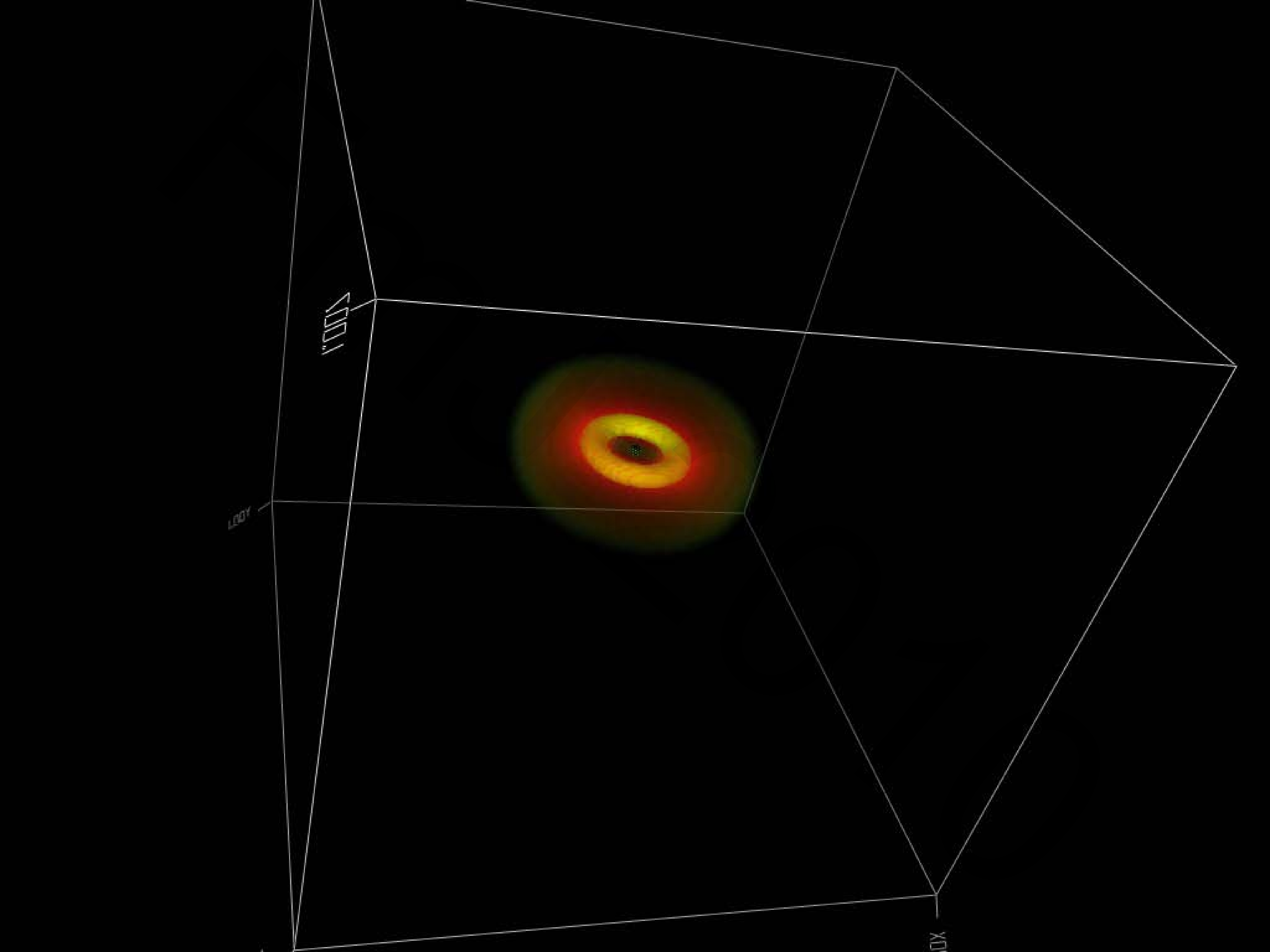


3D GR MHD simulations

(McKinney & RB 2009)

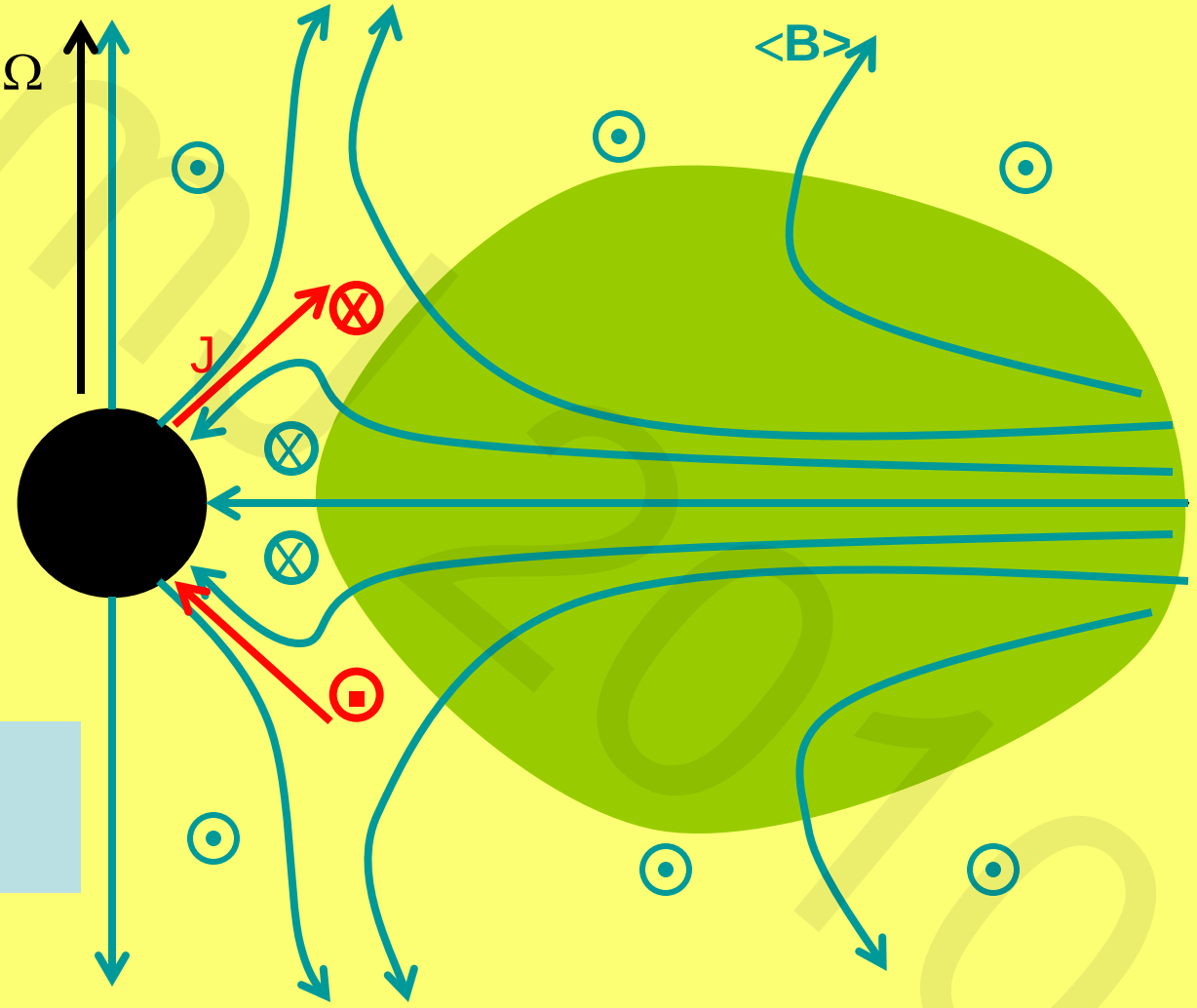
- Dipolar jets can be stable to r ~ 1000m with Γ~10
- m=1 helical instability
- Can compute time variation from simple emissivity models
  - Dominated by relativistic beaming
  - Work in progress
- Quadrupolar jets unstable!
  - Current cone, mass loading





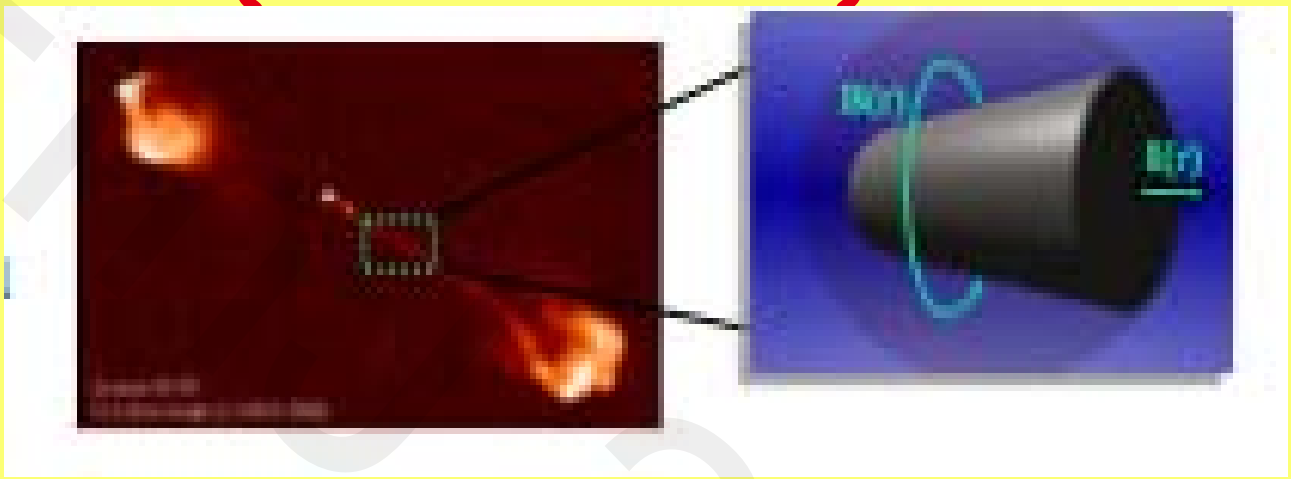
On the Electrodynamics of Moving Bodies

Even field
Odd current



Camenzind, Koide

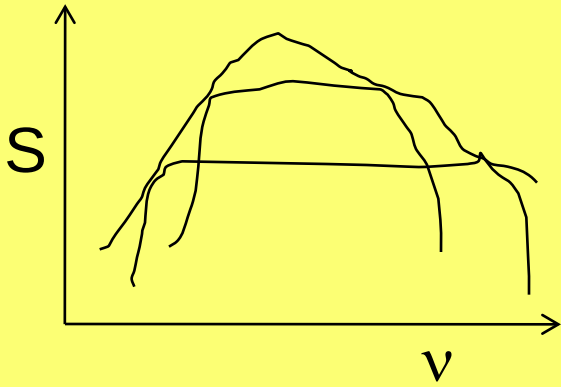
Are pinched jets electromagnetic? (Lisanti & RB)



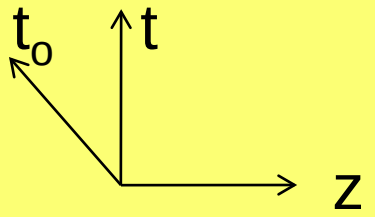
- Simple, axisymmetic model of pinched (current-carrying) jet
- Stabilized by motion and expansion?
- For reasonable current and velocity distributions, L_{mech} ~ 3-20 L_{EM}

Radiative Elements

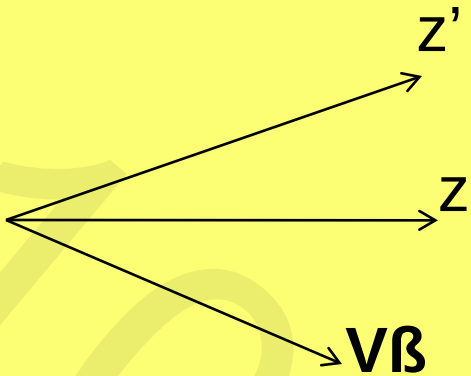
- Doppler boosting
- Radio photosphere, r ~ λ
- Gammasphere, r ~ E?
  - Internal, external radiation
- Shocks – internal, local
- Impulsive acceleration of 100 TeV electrons
- Polarisation



"Observing" Simulated Jets Synchrotron Radiation



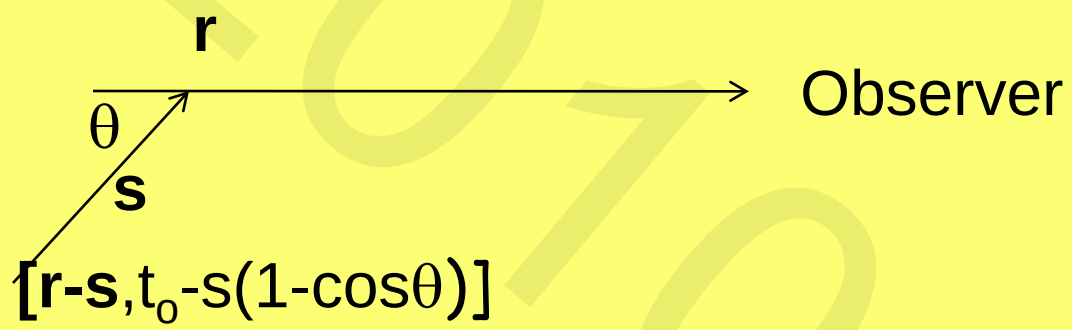
- We know P', B', N', V on grid
- Work in jet frame
- Rotate spatial grid so that observer along z direction
- Shear in t – z space introducing t_o=t-z



- Make emission model
  - eg $j' \sim P' B'^{3/2} \nu^{-1/2}$; $\kappa \sim P' B'^{2} \nu^{-3}$
- Polarization – perpendicular to projected field in cm frame

"Observing" Simulated Jets Inverse Compton Radiation

- Work in jet frame
- Compute radiation along all rays from earlier observer times
- Transform into comoving frame
- Compute j'_{ν}



"Observing" Simulated Jets Pair Opacity

- External and internal radiation
- Internal radiation varies

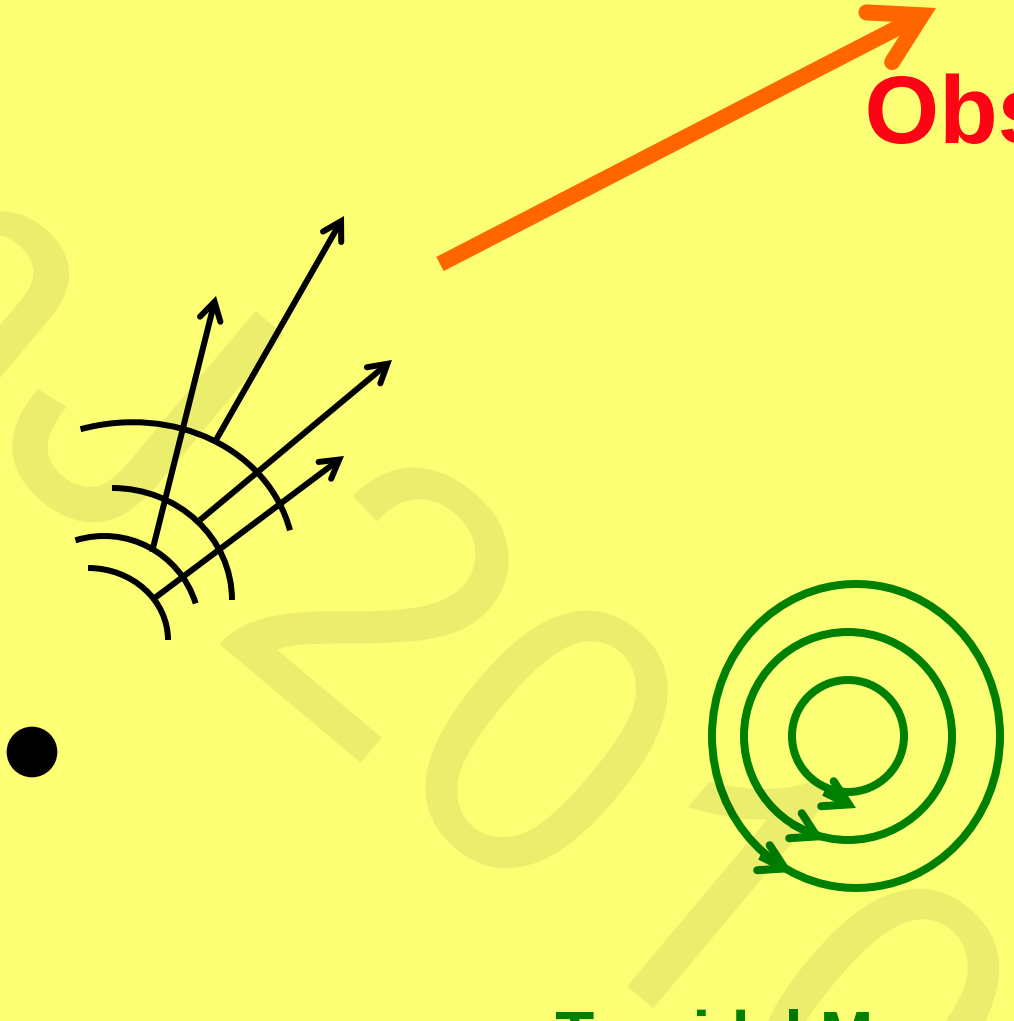
Dipolar Jets

- **Features that are seen are quite unpredictable!**

Quivering Jets

- Observe γ-rays (and optical in 3C279)
- Gammasphere $\tau_{\gamma\gamma}$~1, 100-1000m ~ Eγ
- Rapid variation associated with convected flow of features (2min in Mkn 501)
- Slow variation associated with change of jet direction on time scale determined by dynamics of disk (precession?) or limited by inertia of surrounding medium or both as in wave mode.

Moving caps model



What is to be Done!

- Suite of R(M)HD simulations
- Set of particle, field, radiation prescriptions
- Blind tests for observers!
- View from full range of angles
- Imaging, fluxes, polarization
  - Radio, optical, X-ray, γ-ray…
- Impose observational selection, beams…
  - Test statistical procedures
- Compare with simple models and phenomenological practices
- GRB, XRB jets