The role of Magnetic Fields in the SMBH Environment

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2nd WG#4 MP0905 Meeting
Valencia, 15-November-2010
Physics of Compact Jets (I)

Jets are formed in the immediate vicinity of the SMBH.

The collimation of such a jet requires either a large scale poloidal magnetic field threading the disk or a slower and more massive MHD outflow launched at larger disk radii.

Main Motivation: What are the processes acting at the centers of Quasars (AGN)? How are the powerful jets launched and accelerated?
Physics of Compact Jets (II)

- Acceleration and collimation is completed around 1000 Rsch.
- The magnetic field is believed to play an important role in accelerating and collimating extragalactic jets on parsec-scales.
Physics of Compact Jets (III)

- **Region 1:** ultra-compact jets (< 1 pc) → collimation + acceleration
- **Region 2:** parsec-scale flows (~10 pc) → Relativistic Shocks
- **Region 3:** larger-scale jets (~100 pc) → plasma instabilities dominate
Physics of Compact Jets (III)

- **Region 2**: parsec-scale flows (~10 pc) → Relativistic Shocks
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Fig. 12. Polarized intensity electric vectors (\(\chi\), length proportional to \(p\), 1 mas in the map is equivalent to 10 mJy/beam) overlaid on total intensity (\(I\)) contours (3 mJy/beam \(\times\) 1, 1, 2, 24, 5, 11, 18, 25, ...) and grey scale polarized intensity (\(p\), grey scale up to the peak of brightness, 40.5 mJy/beam) images for 3C 345 at 5 GHz, epoch 1996.81. It is obvious that the electric vector is almost perpendicular to the jet at core separations from 3 to 7 mas.


Fig. 13. Summary of physical properties observed in the two regions of the parsec-scale jet of 3C 345. The values for \(\alpha\) and \(m\) refer to our four observing frequencies (5, 8.4, 15, and 23 GHz), in general.
Helical magnetic fields may appear naturally through the rotation of the accretion disk from which jets are launched and could have an important role in the actual formation and collimation process.
Jet base: 197 x 54 μas = 21 x 6 light days = 69 x 19 Rs
Bifurcation confirmed: jet-width at 0.5 mas: ~174 Rs

It favours models in which the jet is attached more directly to the rotating BH (not to the accretion disk)
Spine-Sheath Polarization Structure

Quasar 1055+018, 5 GHz, VLBA+Y1, Attridge et al. 1999

Linear polarization distribution, contours of $p$, ticks show the orientation of the magnetic field

Total intensity contours + ticks showing the orientation of the magnetic field
Helical B-Fields

LoS B-field towards observer

Positive RM

Gradient in RM is a hint for helical B field

LoS B-field away from observer

RM ≈ 0

Negative RM

spine

Systematic changes in the LOS B-field component across the jet, with increasing values towards the jet-boundaries

sheath
The case of 3C 120

There is a systematic presence of gradients in RM (Faraday Rotation) and degree of polarization across the jet: RM is larger at the southern side; the polzn degree increases towards the edges → Helical Jet

The case of 3C 120

The polzn degree increases with distance from the core →

Interaction of the jet with a cloud at 2-3 mas.
Dominant poloidal B-field ↓

The data are consistent with a helical field in a two fluid jet model (an external RM screen is suggested), consisting of an inner emitting jet and a sheath containing non-relativisitic electrons

The case of 3C 273

There is a stable Faraday Rotation Measure Gradient of 500 rad/m²·mas transverse to the jet axis $\rightarrow$ a helical magnetic field wraps around the jet

The case of 3C 273

It is also found that the degree of polarization increases towards the center → Internal Faraday Rotation is ruled out. It is consistent with a shear layer produced by the interaction of the jet with external medium

Detection of Polarization in a YSO: a magnetic field (~0.2 mG) at a distance of ~100,000 AU, parallel to the jet axis

Carrasco et al. Science (2010), in press
The polarization degree increases towards the jet edges, as expected for a confining magnetic field.

Carrasco et al. Science (2010), in press