Internal rotation and toroidal magnetic field in the inner jet of NRAO150

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Abstract: NRAO 150 is a very prominent millimeter to radio emitting quasar at redshift z = 1.52. In previous studies (Agudo et al. 2007) this source has revealed a fast counterclockwise rotation of the innermost regions of the jet. Since this process is observed in the innermost regions of relativistics jets and must therefore be closely related to the properties of the regions where the jet is formed, collimated, and accelerated, the understanding of this process could be a very useful tool to study the physical process in the innermost part of jets. Despite this the physical origin of this process is still far from being well understood. With the aim to contribute to the understanding of this process we have developed a multi-frequency study at 8,15,22,43 and 86 GHz, analysing in particular the polarization and the cinematic behaviour.

Observations

We present new polarimetric multi-epoch VLBI-imaging observations of NRAO 150 performed at 8, 15, 22, 43, and 86 GHz with the Very Long Baseline Array (VLBA), and the Global Millimeter VLBI Array (GMVA) between 2006 and 2010.

We employed a set of circular Gaussian emission components fitted to the actual visibility data in the UV plane to describe the brightness distribution. These Gaussian emission components are used to follow the trajectories of the most prominent jet emission regions to make an updated characterization of the jet wobbling phenomenon in NRAO 150.

The polarization structure at 86 GHz is fully consistent with that in our 43 GHz images (Fig. 1), hence confirming the good capabilities of the GMVA for both 86 GHz total flux and linear polarization imaging.

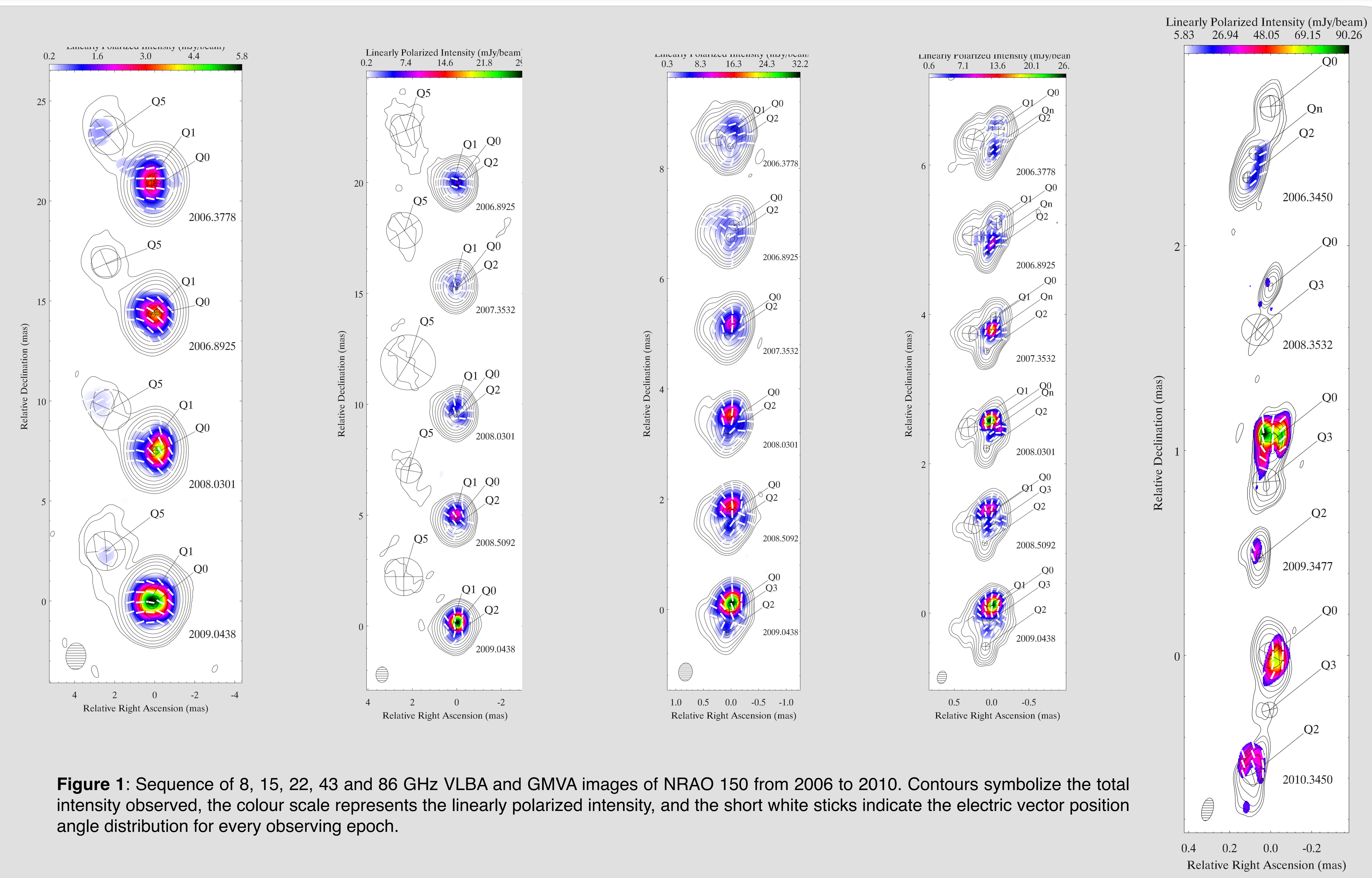
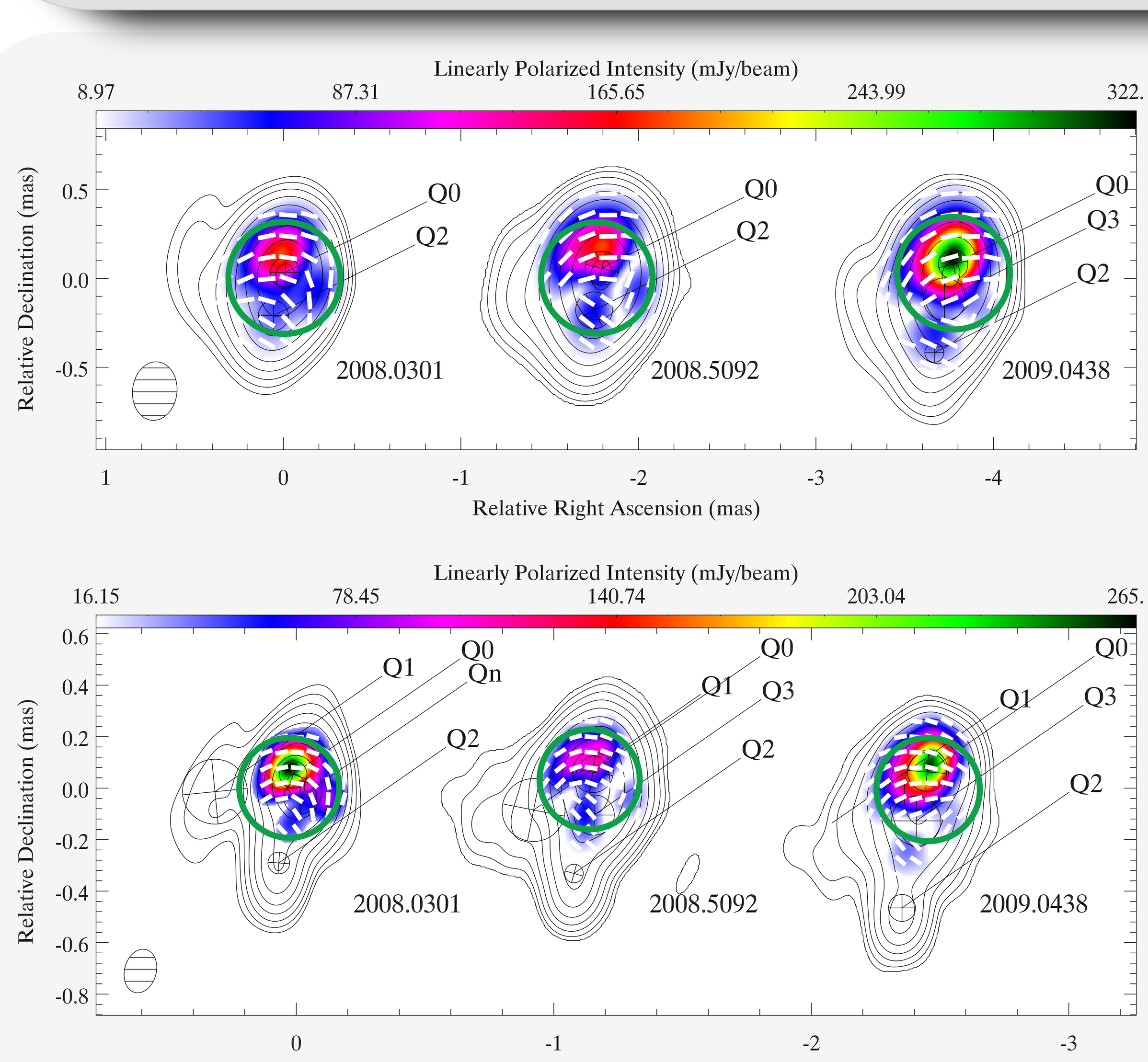


Figure 1: Sequence of 8, 15, 22, 43 and 86 GHz VLBA and GMVA images of NRAO 150 from 2006 to 2010. Contours symbolize the total intensity observed, the colour scale represents the linearly polarized intensity, and the short white sticks indicate the electric vector position angle distribution for every observing epoch.



Evidence for a toroidal component of magnetic field

We report an intriguing tendency of the magnetic vector position angle (that may be identified with the projected magnetic field of the jet in the plane of the sky) to distribute with a configuration that is fully consistent with a circular geometry (Fig. 2). This is especially easy to observe in our last three observing epochs at both 22 GHz and 43 GHz, in which the linear polarization degree is larger and the magnetic field is therefore most probably dominated by a better ordered component than in previous observing epochs. This exceptional polarization structure can only be explained in a consistent way by invoking the toroidal component of the magnetic field as seen across its cross section when the jet is observed essentially face on. This structure is observed in the innermost regions of the jet observed at higher frequencies.

To our knowledge, this is the first time that a jet source observed within a very small angle to the line of sight shows direct evidence of the toroidal component of the magnetic field in an extragalactic relativistic jet.

Figure 2: 22 GHz (top) and 43 GHz (bottom) magnetic vector position angle distributions (symbolized by the short white bars) for the last three observing epochs in our program as projected on the plane of the sky. The green line represents the toroidal component of the magnetic field that could produce the observed magnetic vector distribution.

Jet internal rotation

With the aim to explain the kinematic behaviour we assume a model in which the innermost jet emission regions move rotating around the jet axis when the jet is seen face-on – which is approximately the case of NRAO 150. These trajectories may be produced by a helical or quasi-helical magnetic field threading the innermost, magnetically dominated regions of the jet. If this is the case, the material has to follow the field lines, hence also tracing bent trajectories around the jet axis.

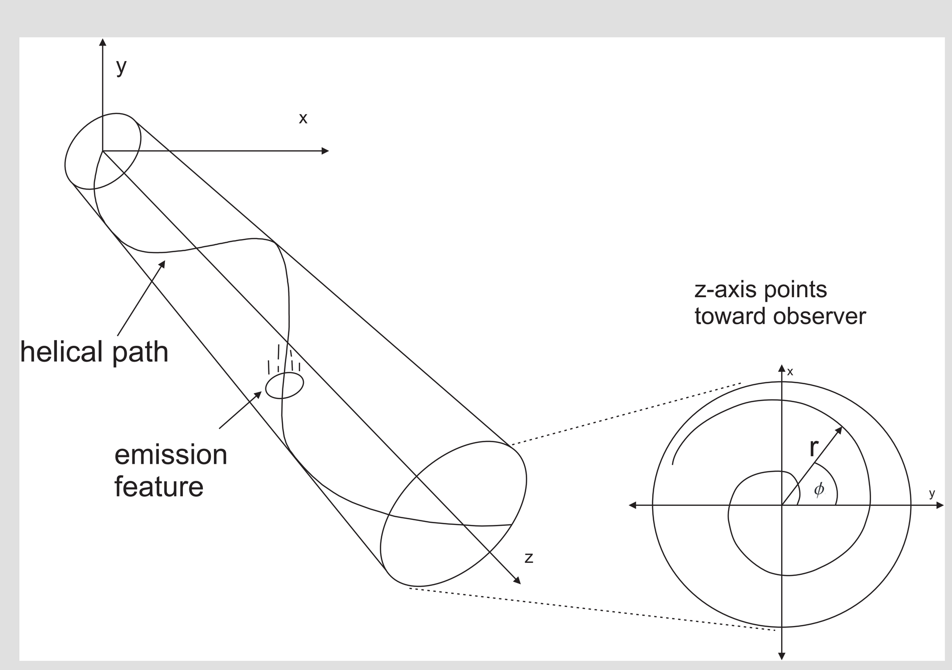


Figure 3: Conceptual representation of the new model proposed to explain the bent trajectories of emission features in the 43 GHz images of NRAO 150.

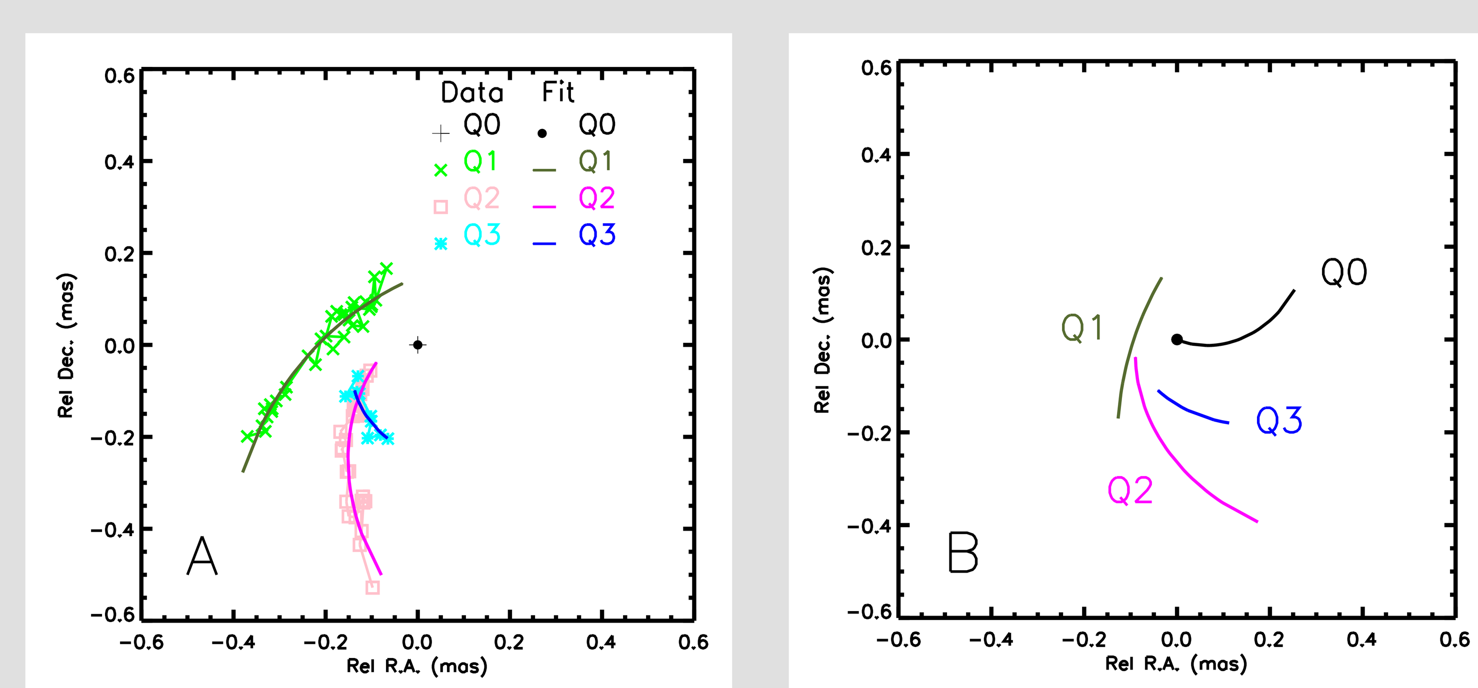


Figure 4: A) Positions of 43 GHz model fitted components as observed on the plane of the sky when the Q0 component is considered to remain stationary at (0, 0). **B)** Best-fit trajectories of emission features as given by our new kinematic scenario. The black line symbolizes the trajectory of Q0 (now describing a bent trajectory around the new (0, 0) position),

We used a χ2 minimization scheme to look for the best-fit values of cinematic parameters.

The trajectories provided by our best fit are graphically represented for Q0, Q1, Q2, and Q3 in Fig. 4-B, whereas the corresponding fitting parameters are shown in Table 1.

In addition, our best fit to such a simple kinematic-scenario describes rather accurately the observed trajectories of the most prominent 43 GHz model-fit components in NRAO 150, which further supports the initial hypothesis that we are observing the actual rotation of the emitting plasma around its jet axis from a very small (almost negligible) angle of the line of sight to this jet axis. For that, a strong toroidal magnetic field component in the relevant emission regions is required, which is fully consistent with both the high-frequency EVPA distribution observed from 22 GHz to 86 GHz.

Comp	r^{ini} [mas]	v^r [mas/yr]	ϕ^{ini} [°]	ω [°/yr]
Q0	0.16 ± 0.01	0.010 ± 0.002	276.1 ± 5.7	6.33 ± 0.48
Q1	0.03 ± 0.02	0.027 ± 0.004	238.3 ± 11.4	1.14 ± 1.08
Q2	0.21 ± 0.01	0.032 ± 0.002	249.8 ± 5.7	3.40 ± 0.48
Q3	0.15 ± 0.03	0.027 ± 0.005	231.4 ± 6.8	7.67 ± 1.03

Table 1: Best-fit parameters corresponding to the new kinematic model for the 43 GHz structure of NRAO 150.