Neutral hydrogen absorption at milliarcsecond resolutions:
The radio galaxy 3C 293

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Overview

1. Overview of the radio galaxy 3C293
2. Summary of observational results
   - Lower resolution VLA & MERLIN observations
   - HST/MERLIN observations of the jet
   - Combined VLBI, MERLIN & VLA observations of H\textsc{i} absorption & radio jet
Introduction & Observations

- **3C293**
  - Nearby Radio galaxy (D=180Mpc; implies 1″ = 815pc)
  - Significant signs of merger (dust lanes, a nearby companion galaxy)
  - Significant gas content (CO, Evans et al 1999 & HI)
  - Fast gas outflows (Morganti et al 2003)
  - Large scale radio jets/lobes
  - Steep spectrum core

- **Observations**
  - Radio: 1.4 GHz VLA, MERLIN & Global VLBI, 5GHz MERLIN continuum (JET & HI absorption)
  - Optical/IR: HST, NICMOS. (IR Jet)
Large to intermediate scale jets

- VLA B-config 1.35GHz
- Double ~100kpc scale jet
- Bright central core region

- Inner jet PA ~90 degrees
  (Significant change compared to large scale jet)

(Beswick et al 2004)
The inner jet

- At sub-arcsec angular resolutions the inner central few kiloparsec radio jet breaks into multiple components along an east-west orientation.
  - Steeply inverted spectrum of core
  - $\alpha \sim -1$ (Akujor et al 1996)
  - Fitted core size <17pc
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Infrared jet

- HST imaging of the centre of 3C293 at 1.6μm reveals a string of knots of emission coincident with the knots observed in the radio emission.
Infrared jet
Infrared Jet

- Approaching eastern
- Shows weak optical/IR jet emission coincident with the inner radio jet components
The neutral ISM

- 3C293 is a very distorted and dust rich radio galaxy
- Extensive ~NE-SW dust lanes
HI absorption

- Very broad & deep HI absorption seen in sensitive WSRT observations.
- Outflows Jet-ISM interactions…. Toward the inner eastern jet??

(Morganti et al 2003)
HI Absorption

- Extensive MERLIN HI absorption
- Eastern side: Narrow absorption
- Western side: Broad(er) absorption
- Opacities $\sim 0.01 - 0.2$
- $N_H \sim 10^{21}$ atoms$^{-1}$ cm$^{-2}$
The dust distribution is strongly correlated with areas of increased HI opacity.

- Dust and Neutral gas spatially related
- In particular the narrow HI absorption traces the dust lanes
HI distribution

Areas of increase HI

HI Opacity
Narrow absorption

- At mas angular resolution the velocity structure of the narrow component is resolved against the eastern jet.
  - Small velocity gradient
    - Gas and dust rotating in the out reaches of the source.
    - VG ~ 50kms\(^{-1}\)arcsec\(^{-1}\)
Position-Velocity

• On ~200mas angular scales. Velocity gradient centred upon the core(?)
• Or two distinct velocity structures (??)

However stepping up the resolution the absorption breaks up many composite components.
• Lack of illuminating background continuum.
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Conclusions

• 3C293 is both an unusual and enigmatic radio galaxy.
• Steeply inverted radio core
• Radio/IR jet
  – Large PA shifts in the radio jet alignment
    • Jet interaction with the ISM and/or multiple outbursts of activity
      (interaction induced??)
• Extensive HI absorption
  – Deep nuclear absorption ($N_H \sim 10^{21}$ atoms cm$^{-2}$)
  – Narrow absorption is strongly correlated with the dust distribution
  – Broad absorption toward the core and western jet
    • Possible velocity gradient in lower resolution data. Implies central mass $< 10^9$ solar masses ($r<$ few hundred parsecs)
    • At mas resolution gradient breaks up – can be interpreted as independent gas structures.
  – Do not have sensitivity or bandwidth to confirm location of broad HI outflows