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 HI absorption & radio jet

Introduction & Observations

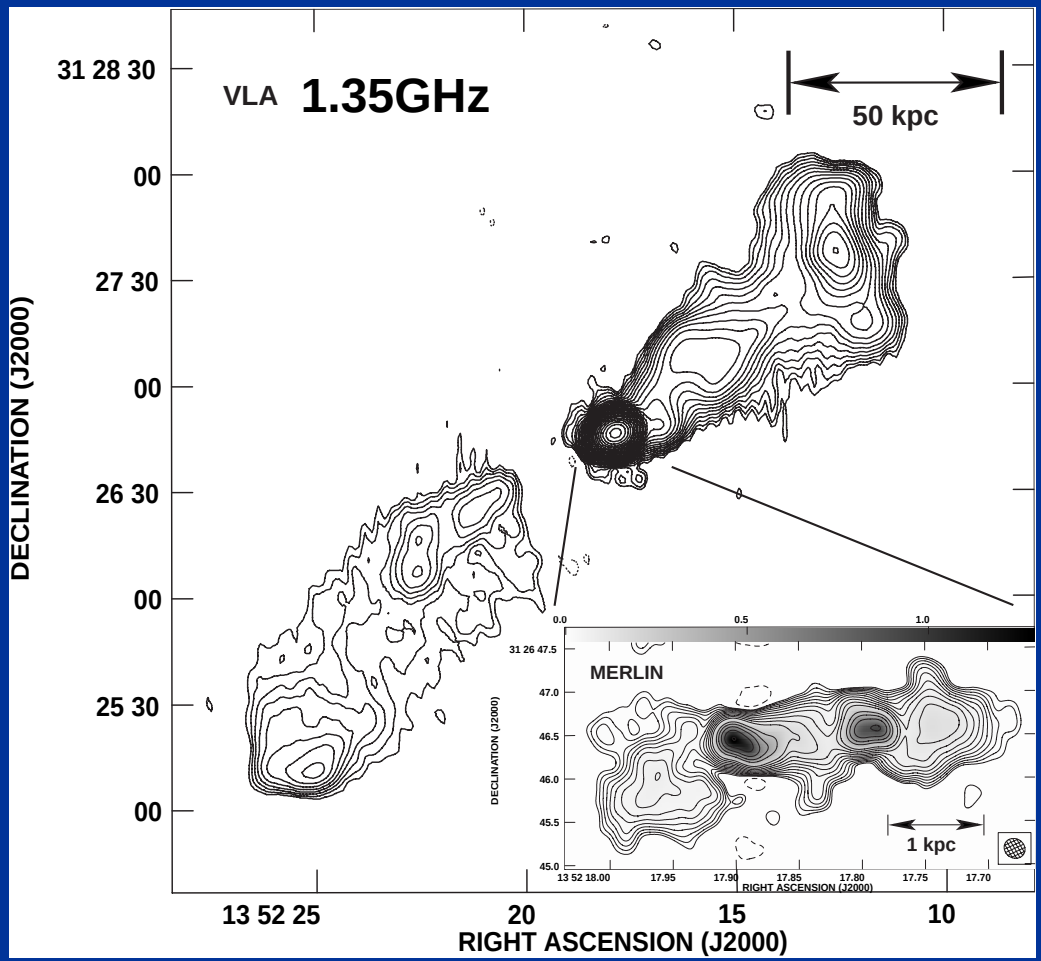
- 3C293
  - Nearby Radio galaxy (D=180Mpc; implies 1” = 815pc)
  - Significant signs of merger (dust lanes, a nearby companion galaxy)
  - Significant gas content (CO, Evans et al 1999 & HI)
  - Fast gas outflows (Morganti et al 2003)
  - Large scale radio jets/lobes
  - Steep spectrum core
- Observations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

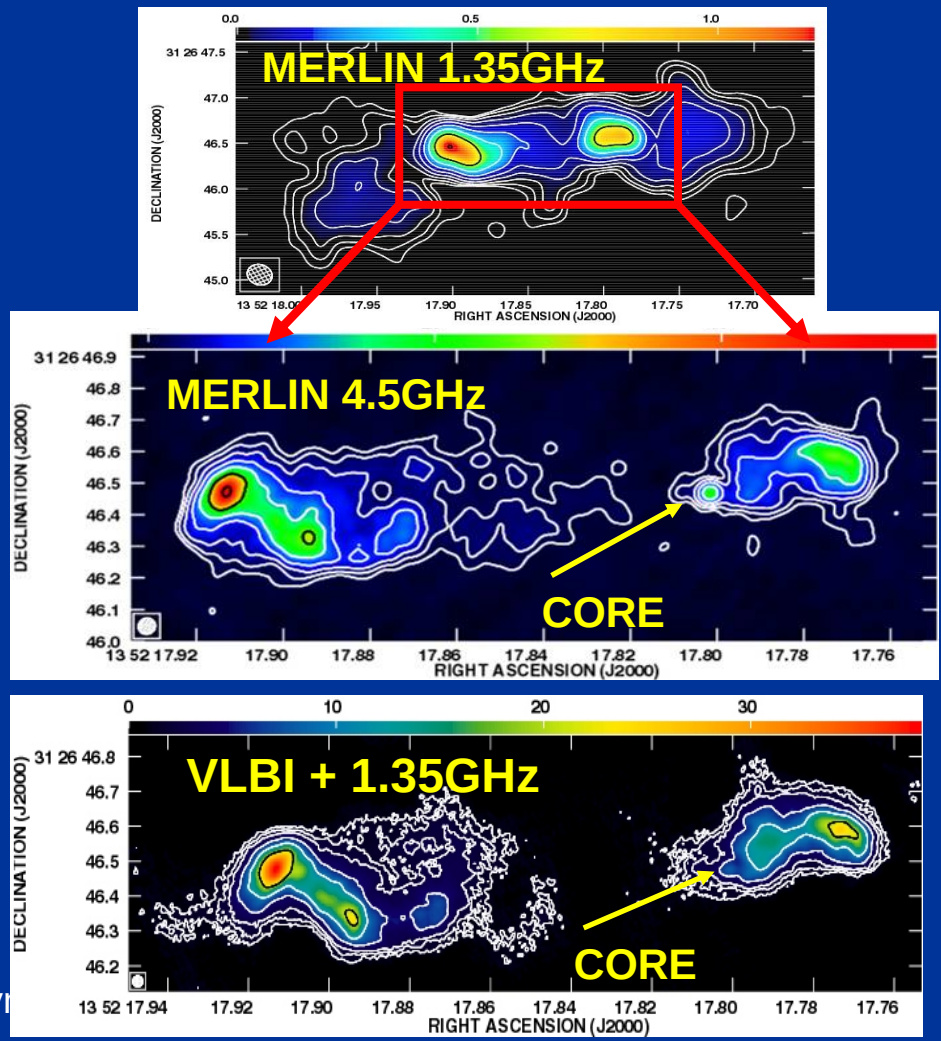
- Inner jet PA ~90 degrees (Significant change compared to large scale jet)

(Beswick et al 2004)



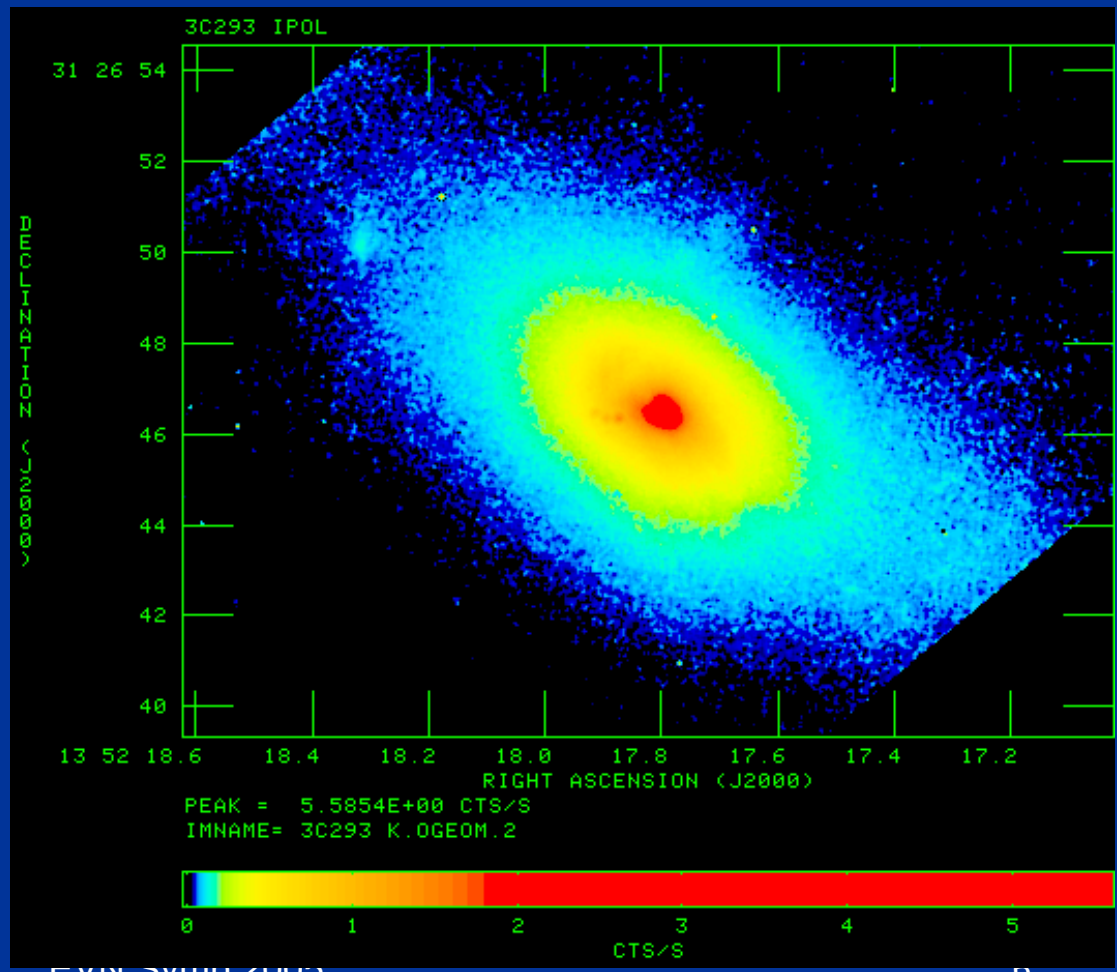
The inner jet

- 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

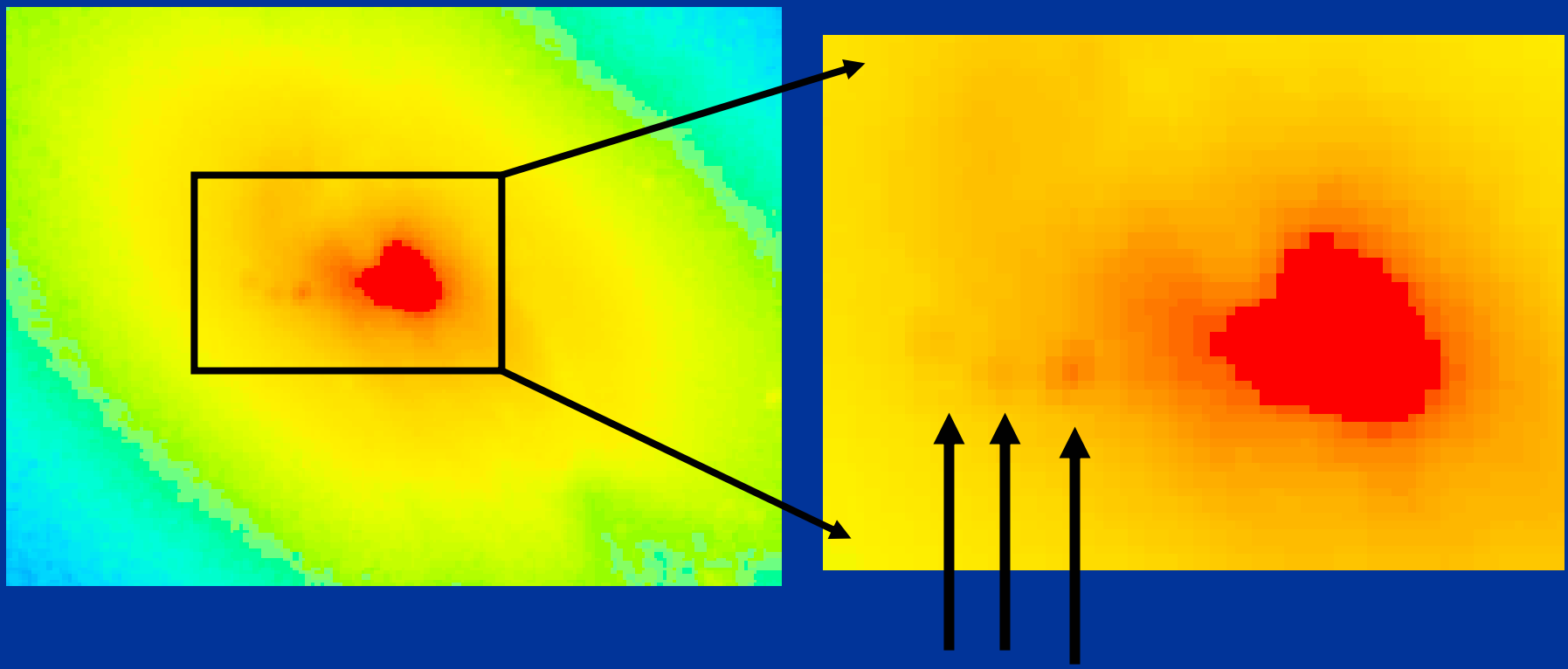


Infrared jet (1)

- **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**

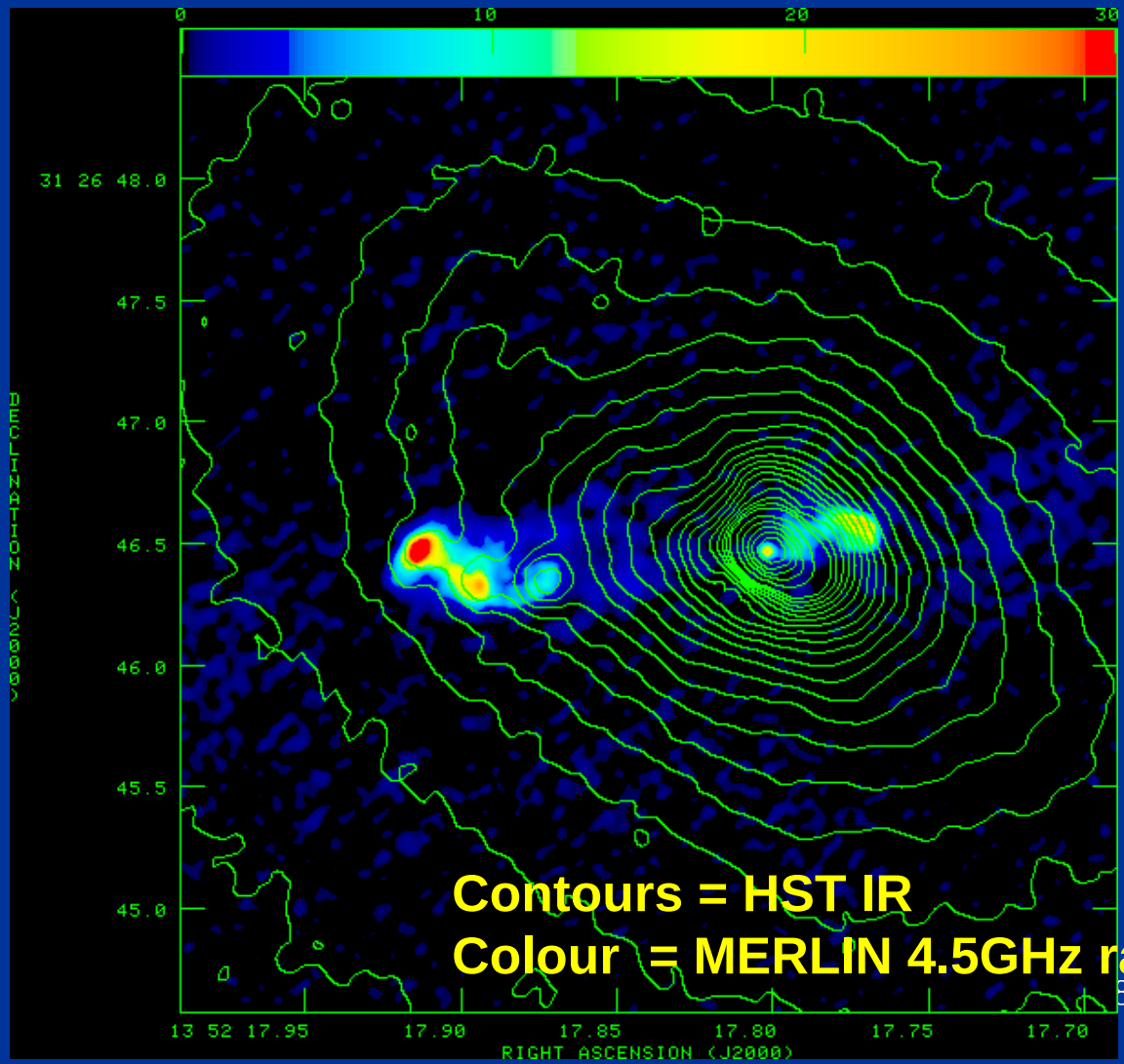


Infrared jet (2)



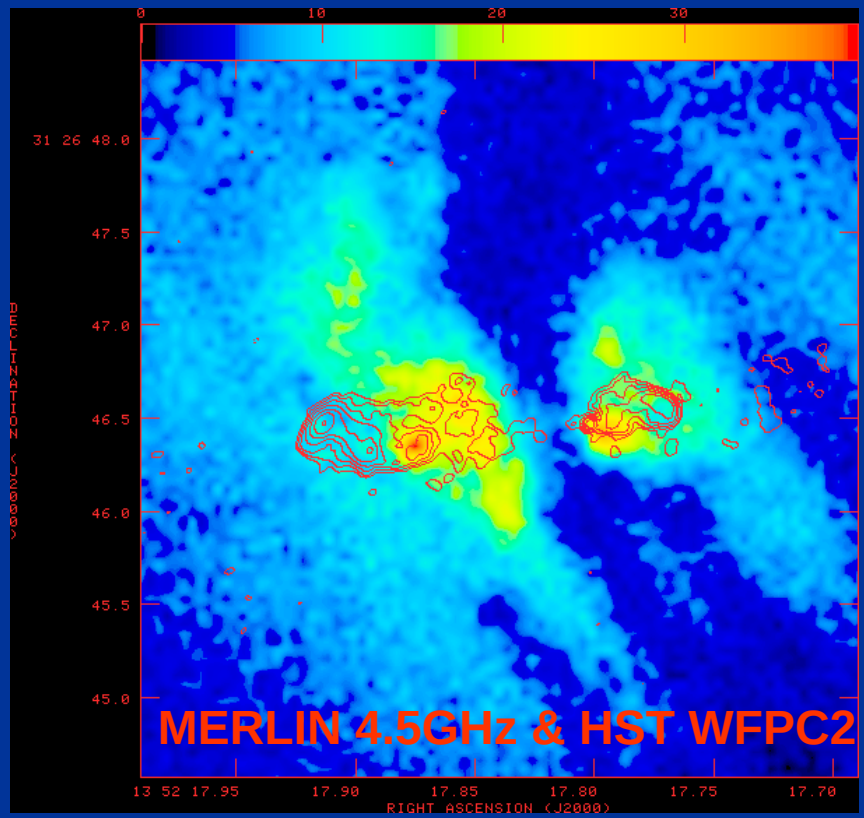
Infrared Jet

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



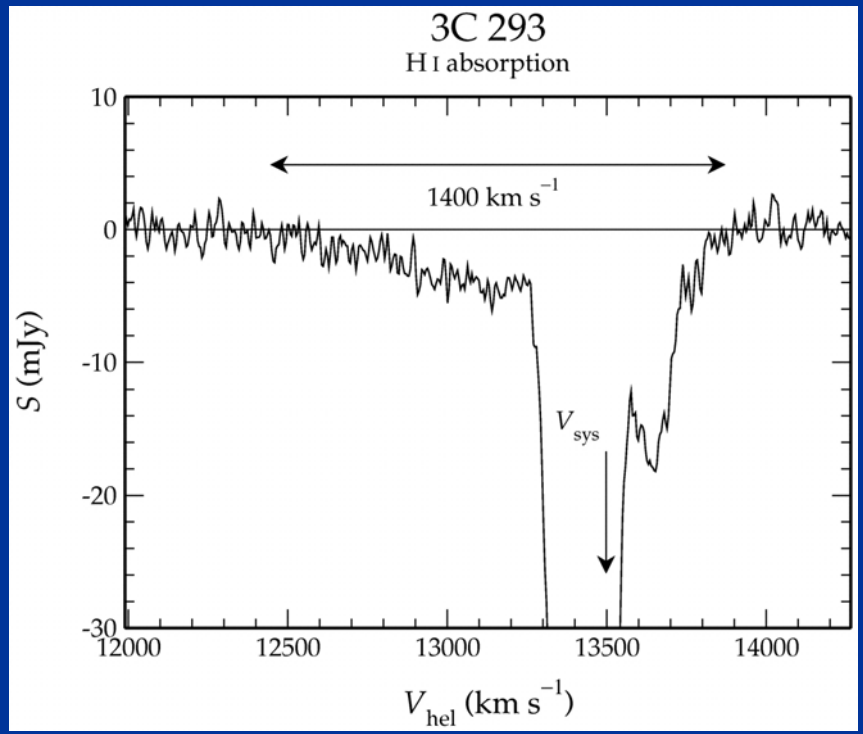
The neutral ISM

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



HI absorption

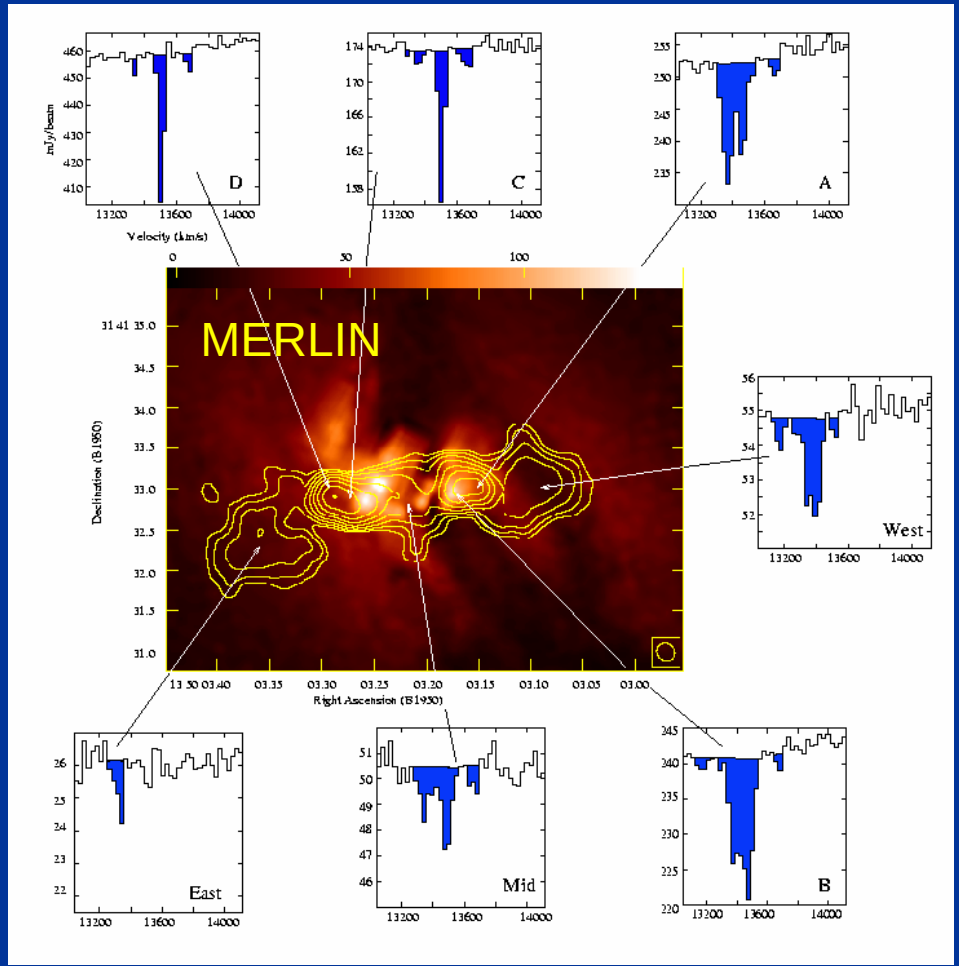
- Very broad & deep HI absorption seen in sensitive WSRT observations.
- Outflows Jet-ISM interactions…. Toward the inner eastern jet??



(Morganti et al 2003)

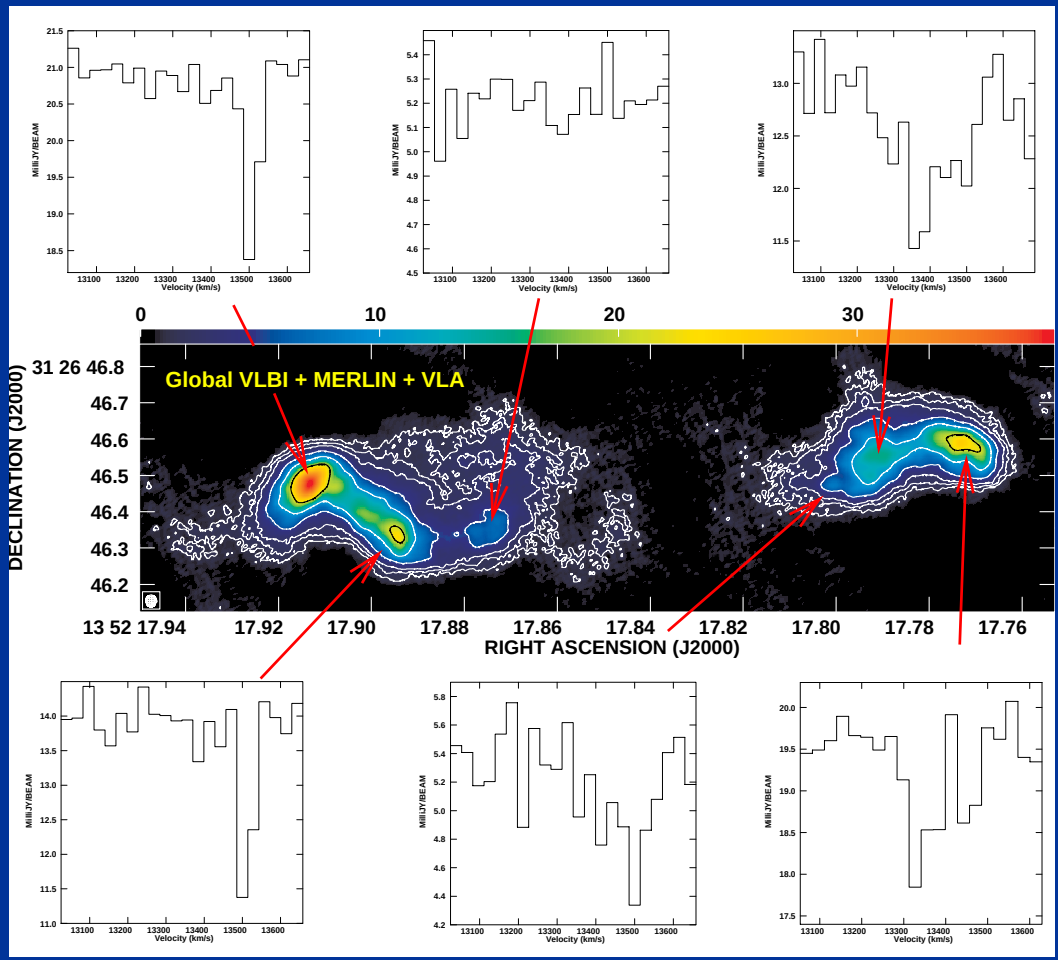
HI Absorption

- Extensive MERLIN HI absorption
- Eastern side :- Narrow absorption
- Western side :- broad(er) absorption
- Opacities ~0.01-> 0.2
- N_H ~10^{21} atoms^{-1}cm^{-2}



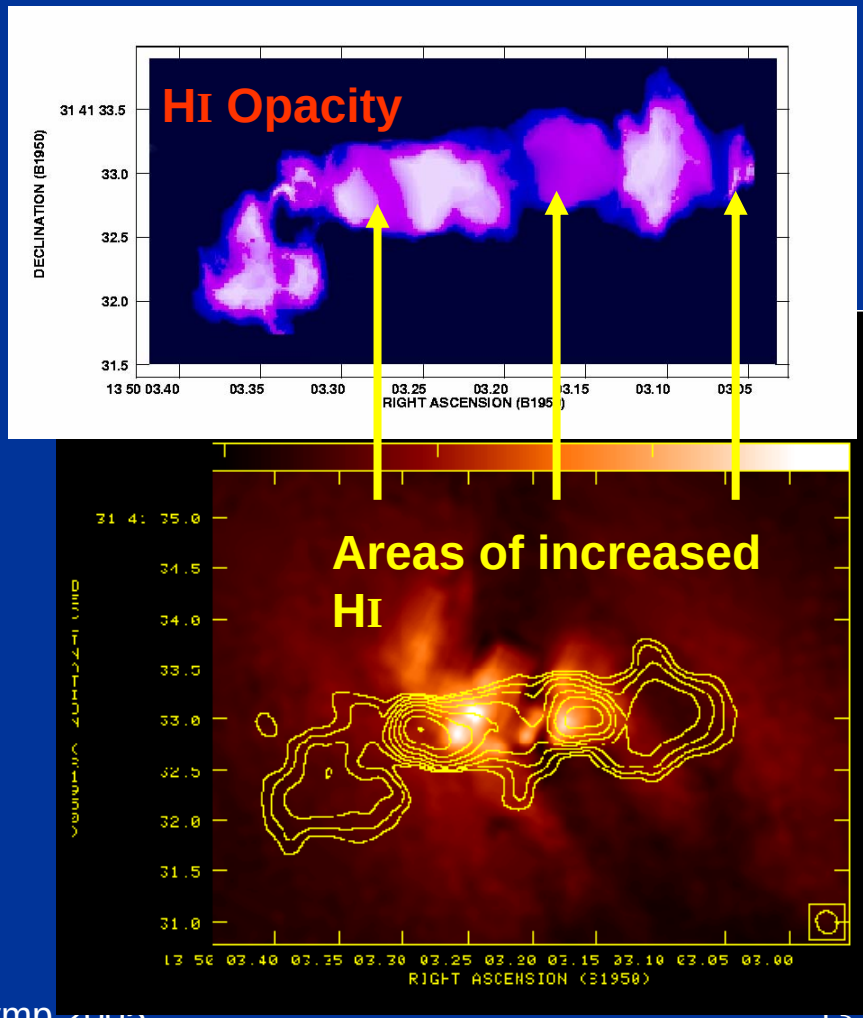
H1 absorption with VLBI

- **Combined VLBI & MERLIN & VLA observations result in an increase in resolution of a factor of ~10 (to 30mas) whilst preserving lower order interferometric spacings**



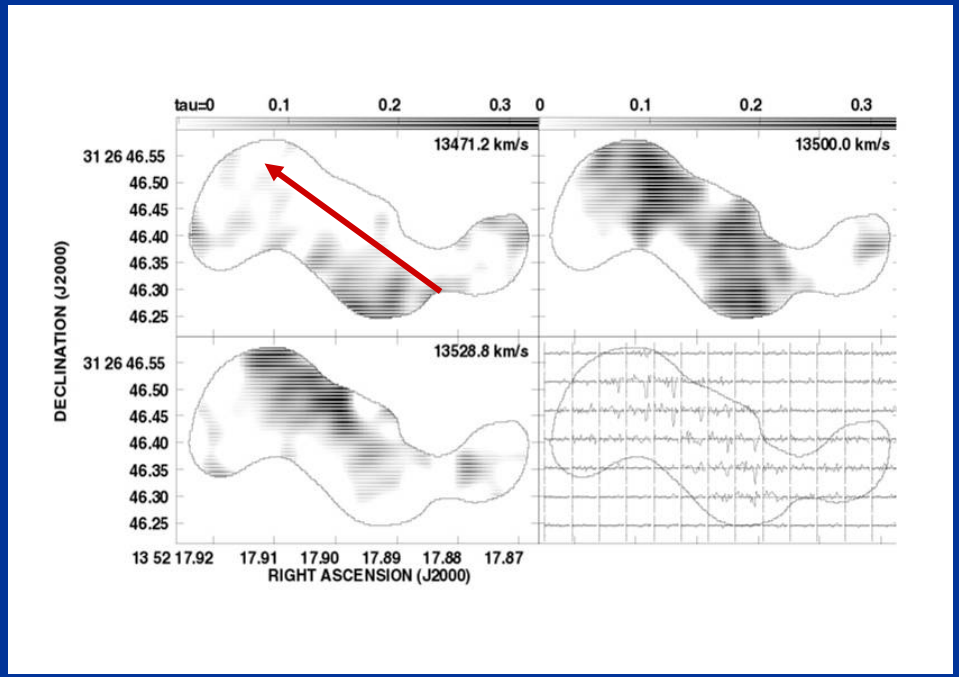
HI distribution

- 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



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 (??)

- On ~200mas angular scales.

Velocity gradient centred upon the core(?)

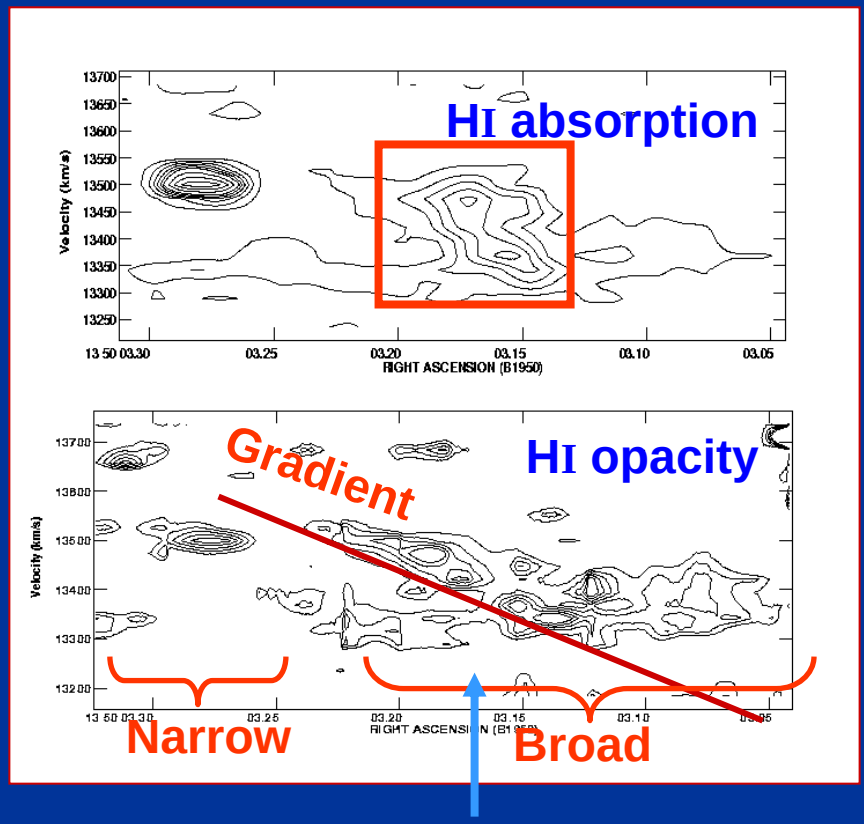
•Implying a rotating gas in the central kpc.

•Or two distinct velocity structures (??)

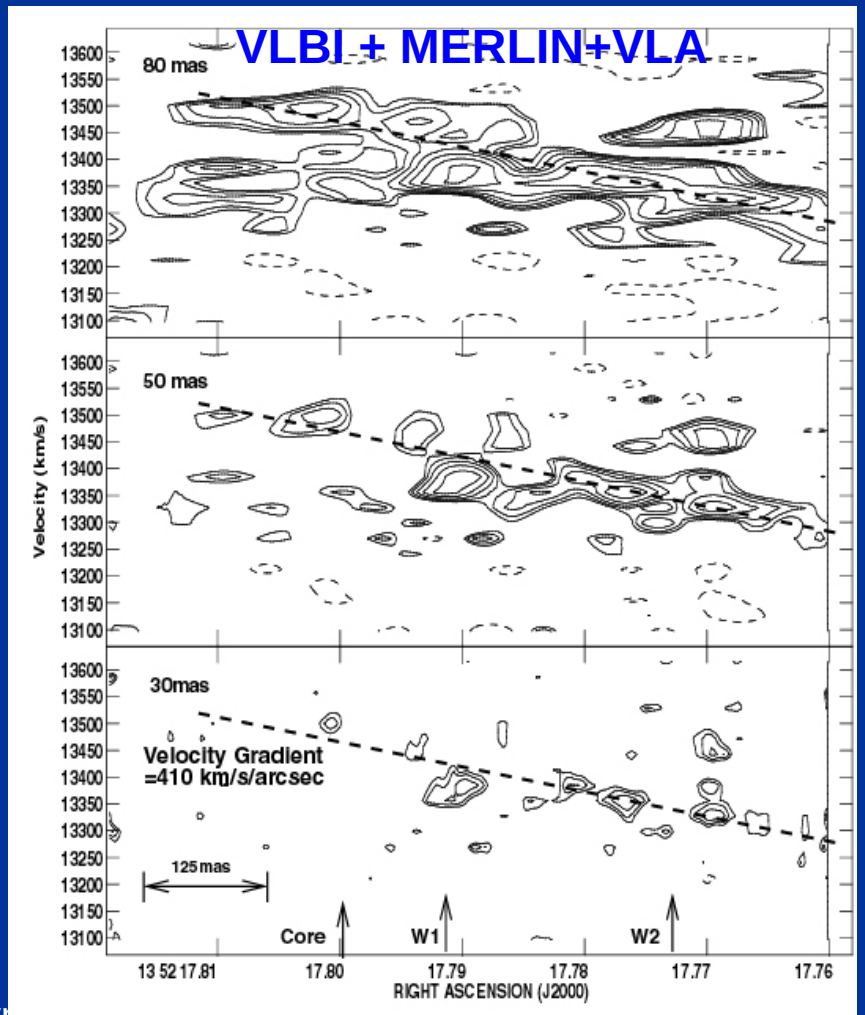
•Possibly not associated?

•blue shifted components related to outflow?

MERLIN – 200mas angular resolution



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



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~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**