A search for polarised emission in jets from high-mass protostars

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Artist’s conception of the massive forming star W33A

Gemini Observatory, artwork by Lynette Cook
Tracers of protostellar jets from massive stars

Molecular transitions (e.g. CO, SiO)

(a): CO(1–0)  
(b): SiO(2–1)

Beuther et al. (2002)

Radio continuum (perp. to disk in blue)

Johnston et al. (2013, in prep.)

Maser polarisation (in disk)

Vlemmings et al. (2010)
Non-thermal ionized jets from massive stars

Multi-frequency ATCA cm continuum observations

Purser et al. (2016)

Spectral index map

Non-thermal ionized jets from massive stars

G310.1420+00.7583A

5.5 GHz
$\sigma = 2.11 \times 10^{-5}$

9.0 GHz
$\sigma = 1.84 \times 10^{-5}$

17.0 GHz
$\sigma = 2.95 \times 10^{-5}$

22.8 GHz
$\sigma = 7.37 \times 10^{-5}$

Spectral index map

$\alpha$

$\alpha_{\text{ext}}$

30000 AU

40000 AU

52m00s 59s 58s 13h51m57s RA (J2000)

34° 48° 42° Dec (J2000)

411530°
Non-thermal ionized jets from massive stars

Questions:

Why is synchrotron emission only seen towards some jets and not others?

How is ~500-1000 km/s material accelerated to relativistic speeds? (Fermi/Diffusive shock acceleration?)

Hatched: jet-like sources Blue: jet knot/lobes

75% of observed jet lobes had negative spectral index
HH 80-81: THE example of linear polarisation in a protostellar jet

Polarisation degree: 10-30%

Carrasco-González et al. (2010)
Our e-MERLIN observations

- Observations of three massive forming stars:
  1) W3 (H$_2$O)-TW
  2) Cepheus A 2
  3) W75 N
- L band 1.5 GHz (1.31-1.76 GHz)
- 450 MHz bandwidth
- Including Lovell telescope
- Spatial resolution $\sim$0.15 $''$ ($\sim$100-200 au at 0.7-1.3 kpc)
- Expected noise:
  $\sim$10 $\mu$Jy/beam
W75 N = nearby region containing massive young stellar objects (YSO)

distance = 1.3 kpc (Rygl et al. 2012)
VLA 1-3: ZAMS B0-2 stars (Shepherd et al. 2004)

VLA 1 likely powers large-scale outflow (Hunter et al. 1994; Shepherd et al. 2003)

Carrasco-Gonzalez et al. (2010)

Jet knot from VLA 3 (220 ± 70 km s\(^{-1}\))

Water and 6.7GHz methanol masers and 1.3cm radio continuum

Surcis et al. (2009)
Results: Total intensity images

8.5 GHz VLA

1.5 GHz e-MERLIN

Beam: 0.22 x 0.14" PA:22.1°

VLA 3 is a point source at L band
< 0.077 x 0.054" or <100 x 70 au

Unfortunately, no polarised emission detected (beautifully empty Q, U and V maps!)

Carrasco-Gonzalez et al. (2010)
Results: no linear polarisation detected

Linear fractional polarisation is <17% in VLA 3

VLA 1: < 75 %
VLA 2: < 66 %
VLA 3: < 17 %
Bc : < 91 %

Upper limits determined from peak intensity of source and 4 x map rms

Obviously need better sensitivity for these sources

Possible explanations of the low-polarisation degree for non-thermal emission:

1. Knots are more turbulent than in the HH80-81 jet
   → more disorganised magnetic field
   → lower polarisation degree

2. The knots have high electron densities or magnetic fields
   → strong Faraday rotation of polarisation angle
   → lower polarisation degree (in wide band)
Results: spectral indices

Previously, 8.5 – 15GHz spectral index of VLA 1 had suggested possible non-thermal emission

\[ \alpha = 0.09 \pm 0.03 \]
\[ \alpha = -0.03 \pm 0.06 \]
\[ \alpha = 0.2 \pm 0.03 \]
\[ \alpha = 0.3 \pm 0.05 \]

Spectral indices calculated with larger frequency baseline are all thermal

Calculated spectral indices between 1.5 and 15.0 GHz data
Summary

- e-MERLIN observations of three massive forming stars with jets to search for linearly polarised emission
- L band observations at 1.5 GHz
- Spec. res. ~0.15” (100-200 au at 0.7-1.3 kpc)
- First results for W75N region
- Linearly polarised emission is not detected (<17% for core VLA 3)
- Spectral indices for core and knots are all consistent with free-free emission
- Conclusion: move on to other two objects!