Magnetic fields in HVCs

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Cloud lifetime

Putman, Peek, & Joung (2012 ARA&A)
Putman, Saul, & Mets (2011 MNRAS)

Magnetic fields

Hydrodynamics: HVCs should lose much of their neutral H before reaching the disk

- Magnetic fields could stabilise clouds
- Few numerical simulations (Konz et al 2002, Santillan et al 2004) or observations to date

Measure rotation measure using Faraday rotation

- $\text{RM} \propto \int n_e B_{||} \, ds$
Rotation measure

Figure 3. Plot of 37,543 RM values over the sky north of $\delta = -40^\circ$. Red circles are positive rotation measure and blue circles are negative. The size of the circle scales linearly with magnitude of rotation measure.

Faraday rotation towards extragalactic point sources from NVSS, $p > 0.4$ mJy
HVC287.5+22.5+240

HVC in Leading Arm of Magellanic System
- Head-tail morphology

HVC287.5+22.5+240

Estimate magnetic field

- WHAM Hα: EM < 0.09 pc cm\(^{-6}\)
  - with assumptions,
    \(N(H^+)< 3.6 \times 10^{19} \text{ cm}^{-2}\)
  - \(N(H \text{ I}) > 2 \times 10^{19} \text{ cm}^{-2}\)
- \(RM \propto n_e B_{\parallel} L\) implies \(B_{\parallel} \gtrsim 6 \mu \text{G}\) (towards observer)

\[\begin{align*}
\text{HI} \\
RM_{\text{HVC}} > +\sigma \\
RM_{\text{HVC}} < -\sigma \\
|RM_{\text{HVC}}| < \sigma
\end{align*}\]

Smith Cloud

H I $v_{GSR} = +247$ km/s ($v_{LSR} = +100$ km/s at head)

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Smith Cloud

\[ H \, I \, \nu_{GSR} = +247 \, \text{km/s} \]
\[ (\nu_{LSR} = +100 \, \text{km/s at head}) \]

RM > 0
RM < 0

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Decelerated gas

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Hα, H I, and RM5s

+40 km/s H I
+100 km/s H I
+40 km/s WHAM-NSS Hα (grayscale)

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Hα, H I, and RMss

+40 km/s H I
+100 km/s H I
+40 km/s WHAM-NSS Hα (grayscale)
RM_{HVC} > 0
RM_{HVC} < 0

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Hα, H I, and RM

\[ \text{RM}_{\text{HVC}} > 0 \]
\[ \text{RM}_{\text{HVC}} < 0 \]

\[
\begin{align*}
    n_e & \approx \sqrt{\frac{\text{EM}}{L_{\text{H}^+}}} \\
    B_{||} & \approx \frac{\text{RM}}{0.81n_e L_{\text{H}^+}} \\
    & = \frac{\text{RM}}{0.81(L_{\text{H}^+} + \text{EM})^{1/2}}
\end{align*}
\]

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Hα, H I, and RMs

+40 km/s H I
+100 km/s H I
+40 km/s WHAM-NSS Hα (grayscale)

\( \langle \text{RM} \rangle = 95 \text{ rad m}^{-2} \) (\( \sigma = 23 \text{ rad m}^{-2} \))

\( \langle \text{EM} \rangle = 1.1 \text{ pc cm}^{-6} \) (\( \sigma = 0.7 \text{ pc cm}^{-6} \))

\( B_{||} \geq +6 \mu \text{G} \) (towards observer)

\[ n_e \approx \sqrt{\frac{\text{EM}}{L_{H^+}}} \]

\[ B_{||} \approx \frac{\text{RM}}{0.81 n_e L_{H^+}} \]

\[ B_{||} = \frac{\text{RM}}{0.81 (L_{H^+} + \text{EM})^{1/2}} \]

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Conclusions

RM signature evident in two HVCs

• Correlated with H I emission from HVC 287.5+22.5+240 in Leading Arm
  - non-detection of Hα
• Correlated with decelerated H I and Hα in Smith Cloud
  - not correlated with (smooth) Hα at Smith Cloud velocity
• lower limit on $B_{||}$ of $\approx 6 \mu$G in each case
  - $B \sim 4 \mu$G sufficient to balance ram pressure for Leading Arm HVC

These head-tail HVCs are in very different environments

• Real data for MHD simulations?
Thank you

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