Radiative signature of large scale magnetized jets

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Image by: S. Kiehlmann
• Simulation pipeline
• RMHD simulation
• Emission simulation
• Synthetic observation
• Summary/Outlook
Simulation pipeline

**Observations**
- Single dish
- VLBI

**RMHD**
- Ambient medium
- Jet kinematics

**Emission**
- Particle distributions

**Postprocess**
- Obs. array
- Imaging

**R(M)HD simulation**
- Observation at 15GHz
- VLBA observation of NGC 1052 at 15GHz
- Observation at 15GHz
- R(M)HD simulation
- Emission at 15GHz
- Emission at 230GHz

**Array properties + uv coverage**
- Imaging
Simulations

Ingredients for jet simulations:

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<th>Jet model</th>
<th>emission model</th>
<th>synthetic image</th>
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<td>(G)RMHD</td>
<td>thermal, non-thermal</td>
<td>obs. array &amp; imaging</td>
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<td>AMR-VAC, BHAC</td>
<td>synchro.py</td>
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\[
\begin{align*}
\rho_j &= \text{jet density} \\
\rho_a &= \text{ambient density} \\
\vartheta &= \text{viewing angle} \\
\Gamma &= \text{jet Lorentz factor} \\
\hat{\gamma} &= \text{adiabatic index} \\
B &= \text{jet magnetic field} \\
\epsilon_e &= \text{number ratio} \\
\zeta_e &= \text{energy ratio} \\
\epsilon_b &= \text{mag. field} \\
\epsilon_\gamma &= e^{-\gamma} - \text{ratio} \\
s &= \text{spectral slope} \\
\end{align*}
\]
Simulations

Ingredients for jet simulations:

Jet model

- (G)RMHD
- AMR-VAC, BHAC

emission model

- thermal, non-thermal
- synchro.py

synthetic image

- obs. array & imaging

Ref: Fromm et al. 2016
RMHD setup

Spine–Sheath–Jet

Power-law atmosphere \( p \propto r^{-\kappa} \)

\( \kappa = 0.5 \)  \( \kappa = 1.0 \)  \( \kappa = 1.5 \)  \( \kappa = 2.0 \)

Ref: Porth & Komissarov 2014, Komissarov et al. 2015
RMHD results

values at jet nozzle \( \rho_j = 0.01 \rho_a \quad \Gamma = 8 \quad \hat{\gamma} = 13/9 \quad \kappa = 1.0 \)

\[ \sigma \uparrow \quad \Rightarrow \quad v_a \uparrow \quad \Rightarrow \quad r_{\text{jet}} \downarrow \quad \sigma = b^2/w \]

\( \sigma \uparrow \quad \Rightarrow \quad \text{less recollimation shocks} \)
Emission simulation

re-construct non-thermal particle distribution

3D geometry and radiative transfer (adaptive grid) $\rightarrow$ intercell interpolation
Emission results

emission parameters used

\[ \begin{align*}
\vartheta &= 5^\circ \\
\epsilon_e &= 0.3 \\
\epsilon_b &= 0.1 \\
\zeta_e &= 1.0 \\
z &= 1 \\
\end{align*} \]

\[ \begin{align*}
a_{cc} &= 10^6 \\
p &= 2.2 (\alpha = 0.6) \\
\rho_a &= 1.0 \times 10^{-23} \text{ g/cm}^3 \\
R_j &= 3 \times 10^{18} \text{ cm} \\
\end{align*} \]

\[ \sigma = 5 \]

\[ \sigma = 1 \]
Emission results

\[ \nu = 15 \text{GHz}, \ \sigma = 5 \]

\[ \nu_m, \ \sigma = 5.0 \]

\[ \nu = 15 \text{GHz}, \ \sigma = 1 \]

\[ \nu_m, \ \sigma = 1.0 \]
Synthetic images

Observing array: Very Long Baseline Array (VLBA)
Date of observation: 27/03/2017
Observing frequency: 5GHz - 86GHz
On-Off-source: 10min/50min
Antenna diameter: 25m
System temperature: 55K - 65K
Synthetic images

\[ \nu = 15\text{GHz}, \sigma = 5 \]

\[ \nu = 15\text{GHz}, \sigma = 1 \]
Synthetic images

\[ \nu = 15\text{GHz}, \ \sigma = 5 \]
Summary & Outlook

Summary:
- perform RMHD simulations
- compute non-thermal emission
- create synthetic observations
- simulation-to-synthetic observations pipeline

Outlook:
- apply observers analysis technique (spectral index maps, core-shifts, …)
- direct modelling of observations via GA
- compute polarisation
- include radiative losses