Solar Wind – Comet Interaction: Global 3D Hybrid Code Simulation Study

Uwe Motschmann, Thorsten Bagdonat

Institute for Theoretical Physics, Univ Braunschweig, Germany.
The hybrid model

- **Full particle**: Ions & Electrons as particles
  - Complete physics
  - Very expensive
  - Small scales

- **Multi-fluid**: Ions & Electrons as fluid
  - Fast & easy
  - No kinetic effects
  - Large scales

- **Hybrid model**: Ions as particles, electrons as fluid
  - Intermediate scales
Numerical method

- **Gather**: $x, v \Rightarrow \rho, j$
- **Particle Push**: $E, B \Rightarrow x, v$
- **Scatter**: $E, B \Rightarrow E, B$
- **Field update**: $j, \rho \Rightarrow E, B$

Particles are updated according to the equations $E, B, j, \rho$. The cycle $(x, v) \Rightarrow \rho, j \Rightarrow (x, v)$, $E, B \Rightarrow E, B$ is repeated to simulate the plasma behavior.
Classical picture of a strong comet

• Shock
• Cavity
• Turbulence

„Halley“-type comet

compare with [Hopcroft & Chapman, 2001]
The cycloidal motion

Cometary frame: „Test particles“ perform cycloidal motion (pickup)

Solar wind rest frame: „Test particles“ perform a circular motion

magnetic field (B)

relative motion (V)

Lorentz force (V x B)
Small obstacle produces a Mach cone
Weak comet dynamics (Large Scale)

Tail structuring: „bi-ion acoustic wave“

[Bogdanov et al., 1996] (multi fluid)
From a weak to a strong obstacle

Classic, linear Mach cone
Multiple, nonlinear Mach cones
Symmetric case
Multiple shocklets
Parabolic shock
Comet Wirtanen: Simulation of an expected scenario
At 3.5AU Wirtanen has mainly a cycloidal tail
SW is rather undisturbed, no shock, no cavity
Wirtanen at 3.25AU

magnetic field

heavy ions

0.00s  Wirtanen, 3.25AU, 0=1.8*10^{-25}s^{-1}

[Bugdonot & Motschmann, 2001]
Wirtanen at 3AU

0.00s Wirtanen, 3AU, \(\theta = 3 \times 10^{-25} \text{s}^{-1}\)

[Bagdonat & Motzschmann, 2001]
Wirtanen at 2.8AU

magnetic field

heavy ions

0.00s Wirtanen, 2.8AU, $O=7.5\times10^{-25}s^{-1}$

[Bugdonet & Matschmann, 2001]