Modelling cosmic-ray transport in jets as a correlated random walk

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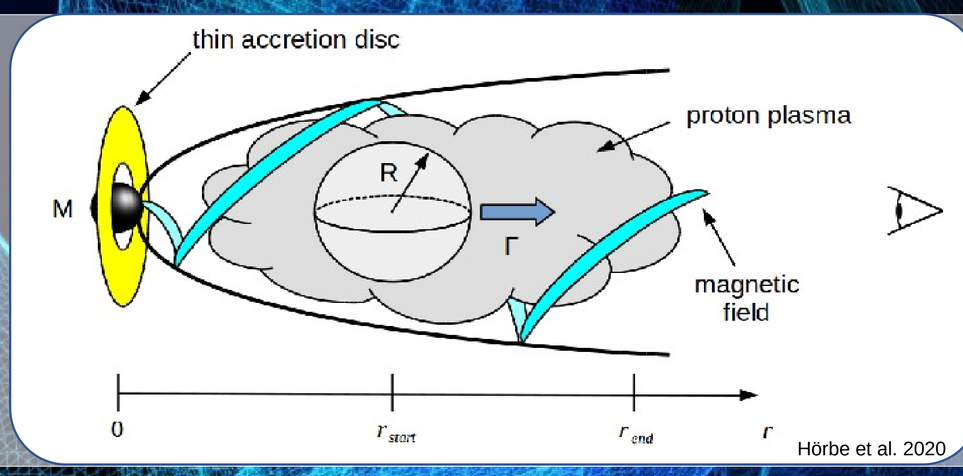
Overview

- This work describes charged particle transport in magnetic fields via a correlated random walk (CRW) in cylindrical coordinates
- Initial, ballistic, and later diffusive phases are modeled correctly → relevant for compact objects such as blobs in AGN jets
- Statistically satisfying the particle distribution described by the transport equation

Motivation

- Relativistic, compact blobs moving along the jet
- Need for modeling transport and interactions
- Solving Eq. of Motion (EOM) exact but slow
- Using a diffusive approach is fast but only valid in the diffusive limit at sufficiently large times
- We present a CRW approach that is fast while describing the statistics correctly



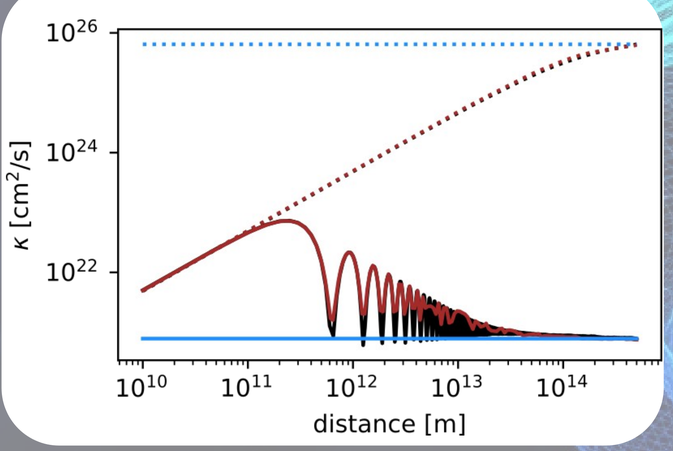
Hörbe et al. 2020

Illustration: DESY, Science Communication Lab

Running diff. coefficients

Compare **CRW, EOM, diffusive**

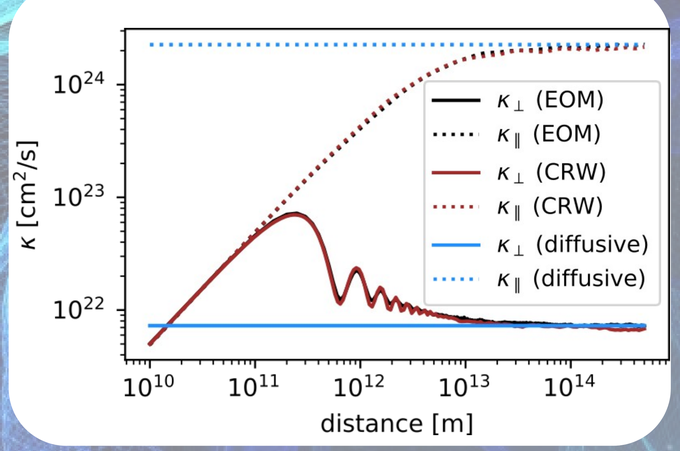
Weak turbulence level



Turbulence level: b/B = **0.1**

- Particles initially gyrate around ordered magnetic field B
- A diffusive approach overestimates parallel diffusion at the beginning

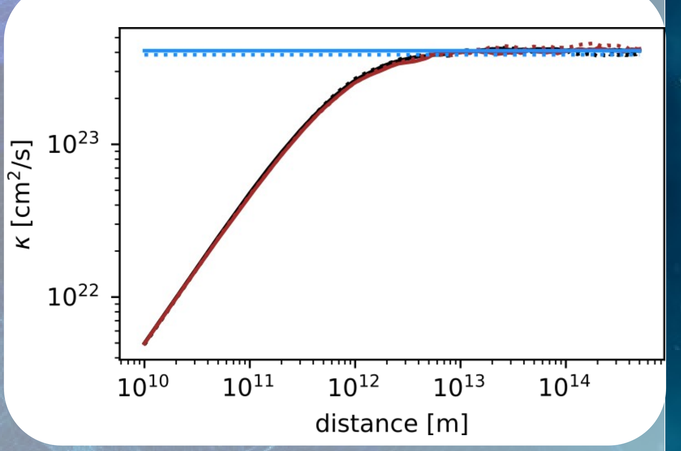
Intermediate turbulence level



Turbulence level: b/B = **0.5**

- Same as for weak turbulence level
- Using CRW in cylindrical coordinates
- However, diffusive limit is reached earlier

Strong turbulence level



No ordered magnetic field: B = **0**

- Isotropic diffusion in turbulence
- Using CRW in Cartesian coordinates
- Diffusion limit is reached earlier than in other cases with $B > 0$

Discuss **results**

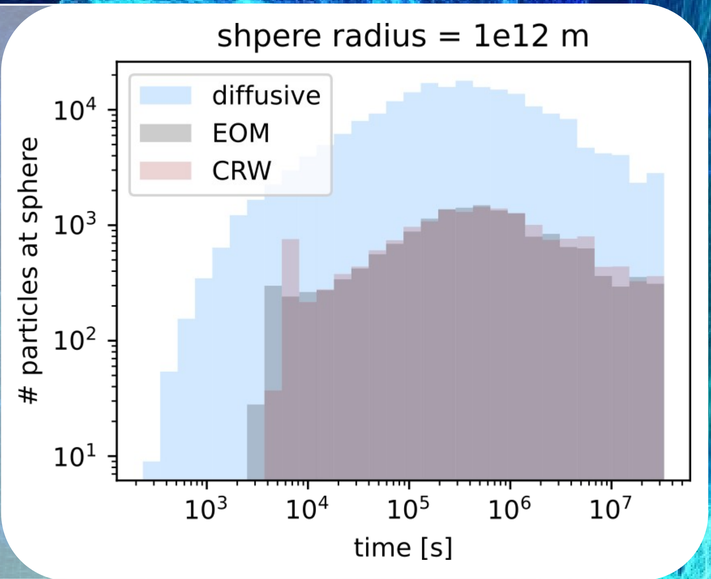
Findings

- CRW and solving EOM result in similar running diffusion coefficients, while a diffusive approach deviates in the initial phase
- CRW and diffusive approach fastest

Escape times

- Production of secondaries in blob
- Strong turbulence and high density in blob
- Number of secondaries depends on time spent in blob of primaries → escape time
- Primaries escape when reaching blob sphere → plot shows escape time from blob

→ Escape time is influenced by choice of transport model (particles are even faster than the speed of light in diffusive approach)



Key findings

- Initial ballistic propagation turns into diffusion in CRW, and EOM, while a diffusive approach cannot describe the initial phase
- Diffusive & CRW much faster than EOM
- A diffusive approach overestimates particles that leave blob
  → diffusive models underestimate the production of secondaries in blob
- CRW gives similar results to EOM

Outlook

- Implementation of energy and turbulence-level dependent diffusion coefficients for CRW
- More realistic tests that include interactions and particle spectrum