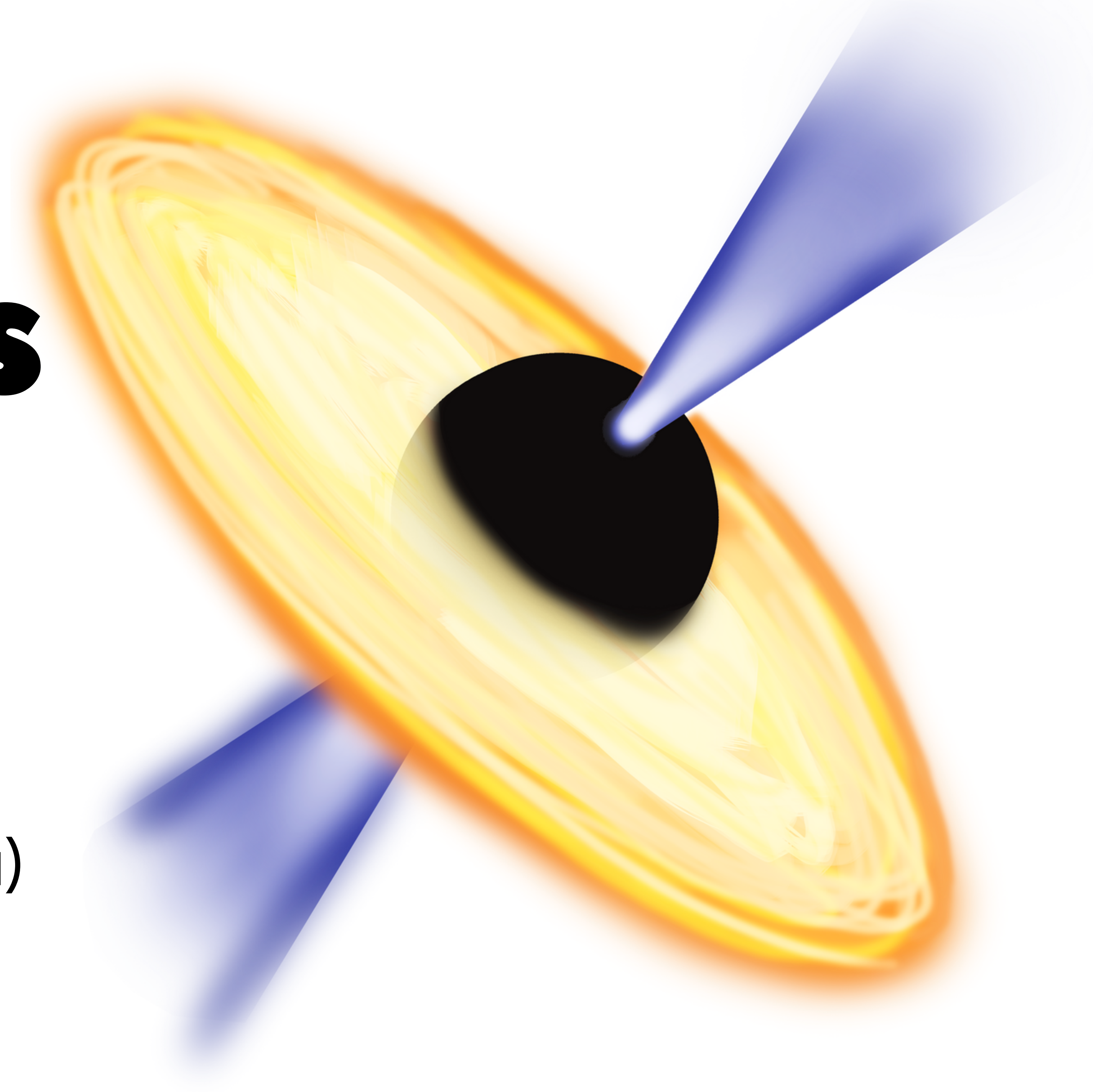
HEPRO VIII Conference, Paris

ROLE OF JET DYNAMICS IN PARTICLE ACCELERATION



Ravi Dubey (*with* **Christian Fendt** & **Bhargav Vaidya**)

Max Planck Institute for Astronomy, Heidelberg

PRESENT WORK

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CrossMark

Particles in Relativistic MHD Jets. I. Role of Jet Dynamics in Particle Acceleration

Ravi Pratap Dubey[1,3], Christian Fendt[1], and Bhargav Vaidya[2]
[1] Max Planck Institute for Astronomy, Königstuhl 17, D-69117 Heidelberg, Germany; dubey@mpia.de, fendt@mpia.de
[2] Indian Institute of Technology Indore, Khandwa Road, Simrol, Indore 453552, India; bvaidya@iiti.ac.in
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Abstract

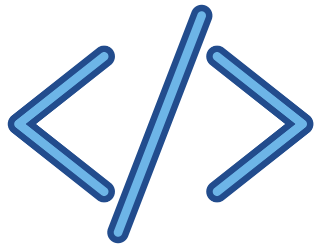
Relativistic jets from (supermassive) black holes are typically observed in nonthermal emission, caused by highly relativistic electrons. Here, we study the interrelation between three-dimensional (special) relativistic magnetohydrodynamics, and particle acceleration in these jets. We inject Lagrangian particles into the jet that are accelerated through diffusive shock acceleration and radiate energy via synchrotron and inverse Compton processes. We investigate the impact of different injection nozzles on the jet dynamics, propagation, and the spectral energy distribution of relativistic particles. We consider three different injection nozzles—injecting steady, variable, and precessing jets. These jets evolve with substantially different dynamics, driving different levels of turbulence and shock structures. The steady jet shows a strong, stationary shock feature, resulting from a head-on collision with an inner back-flow along the jet axis—a jet inside a jet. This shock represents a site for highly

MOTIVATION

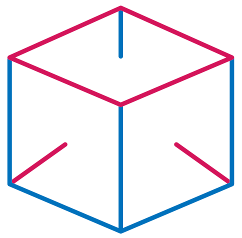
1. Jet dynamics for different injection mechanism
2. Shocks and turbulence in different jets
3. Particle Acceleration through shocks
4. Synthetic spectrum and emission signatures
5. Disentangle dynamics from emission
6. Comparison with observations

SIMULATION SETUP

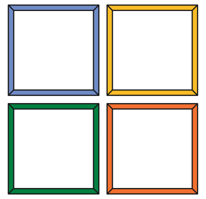
NUMERICAL SETUP



PLUTO code (Mignone et al. 2007) to solve RMHD fluid equations

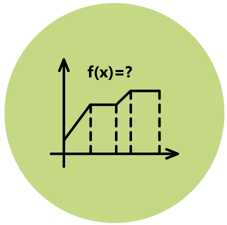


3D uniform Cartesian coordinates

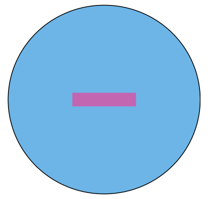


Resolution: 25 grid cells per jet radius

Ambient Medium: uniform, stationary, magnetized



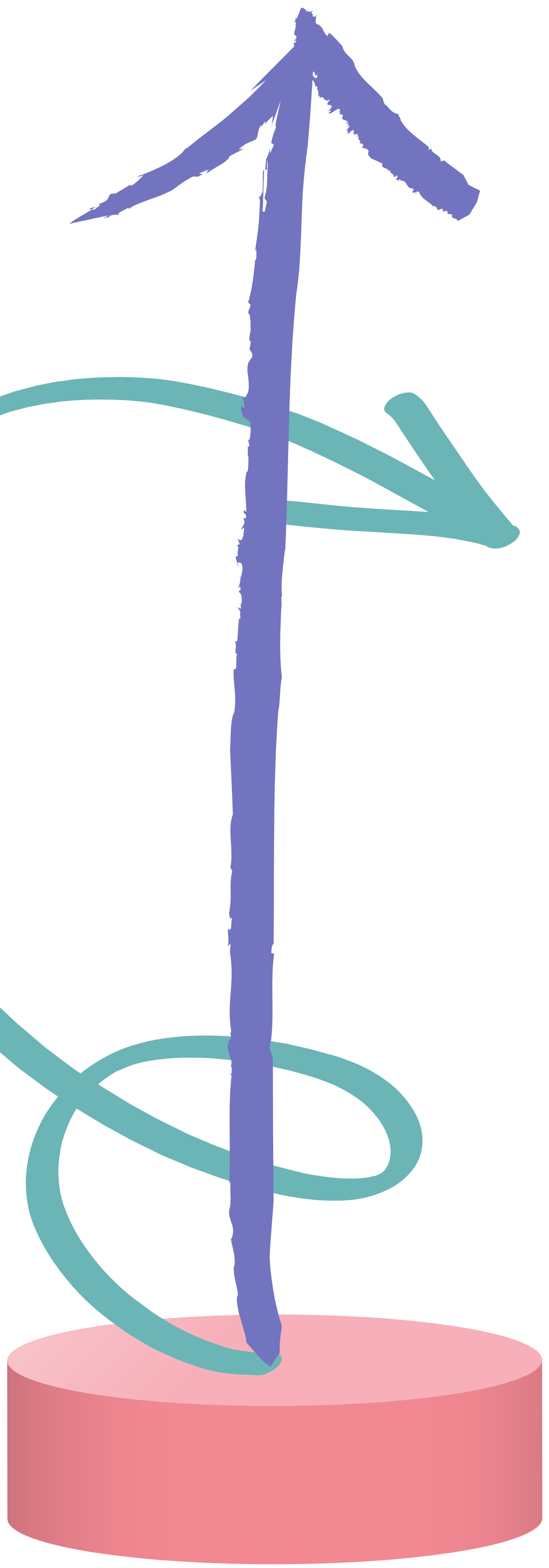
Equation of State: Taub-Matthews EoS for mixture of relativistic and non-relativistic gas



Lagrangian Particles: Diffusive shock acceleration, non-thermal cooling (Vaidya et al. 2018)

JET INJECTION

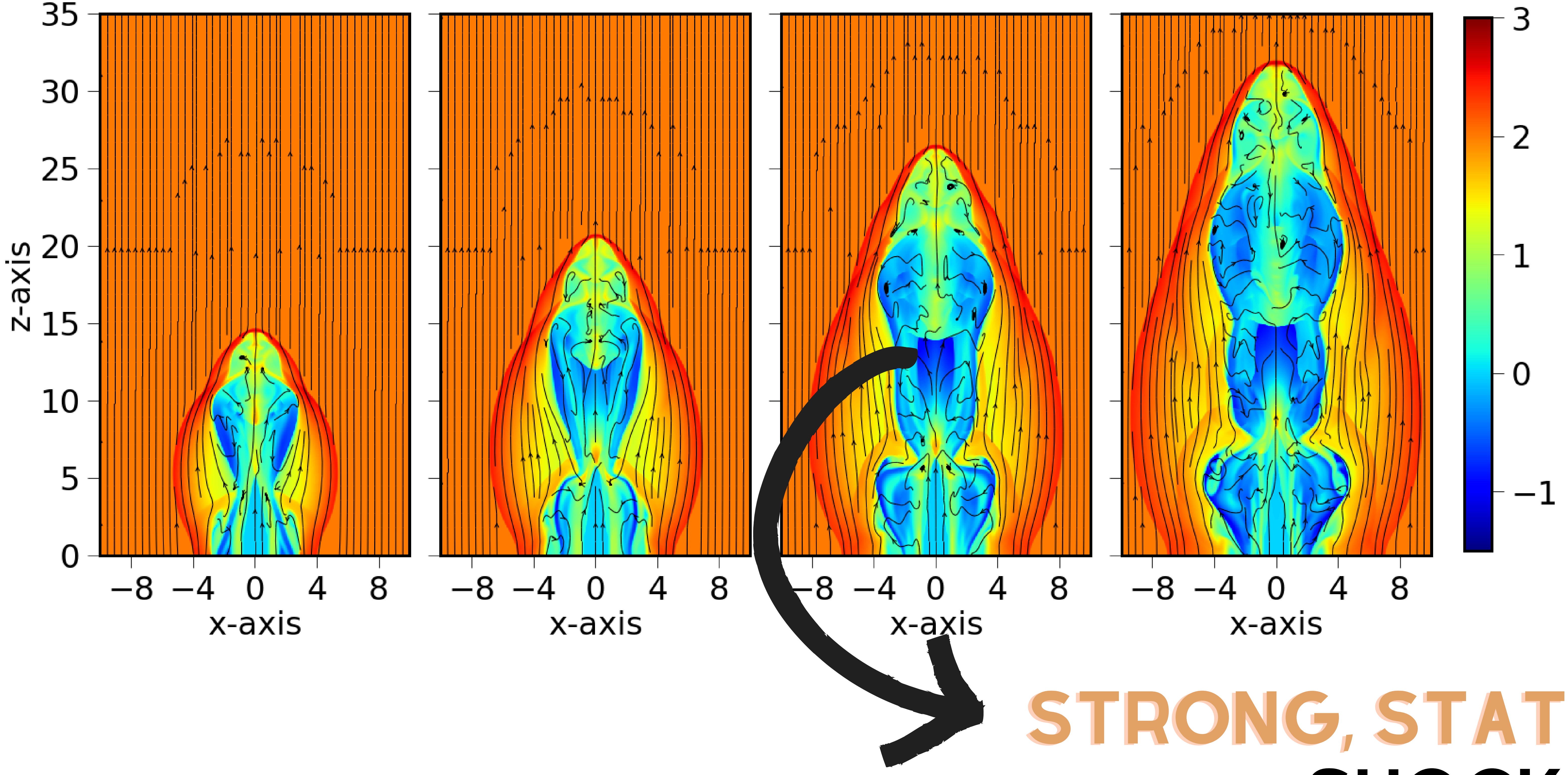
- Jet injection through the injection nozzle
- Important to avoid artificial instabilities
- Adopted injection profiles from Bodo et al. 2019
- Three injection profiles
    - A rotating steady jet with $\gamma = 10$
    - A rotating jet with variable γ
    - A rotating jet precessing about z-axis with $\gamma = 10$



pc-scale jets

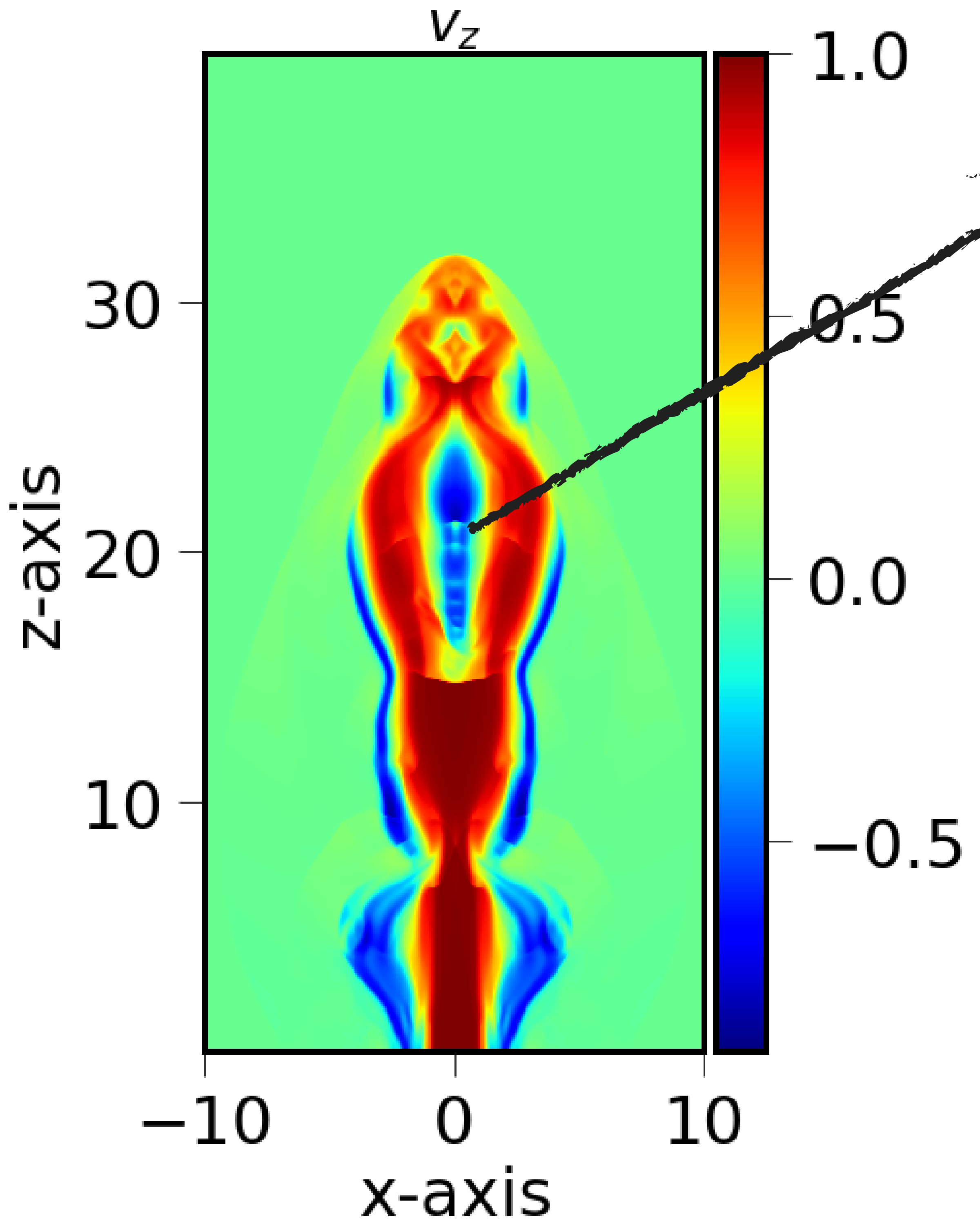
RESULTS

STEADY JET



STRONG, STATIONARY SHOCK

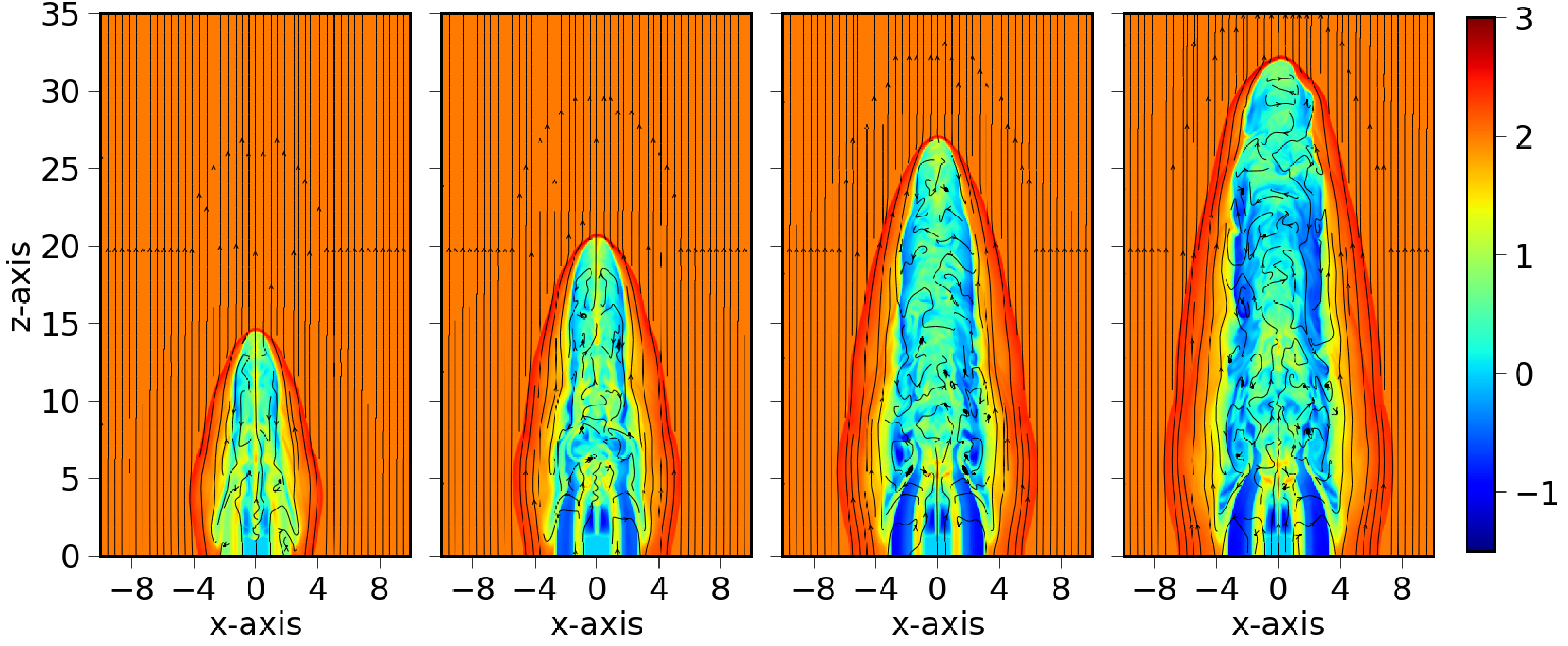
STATIONARY SHOCK



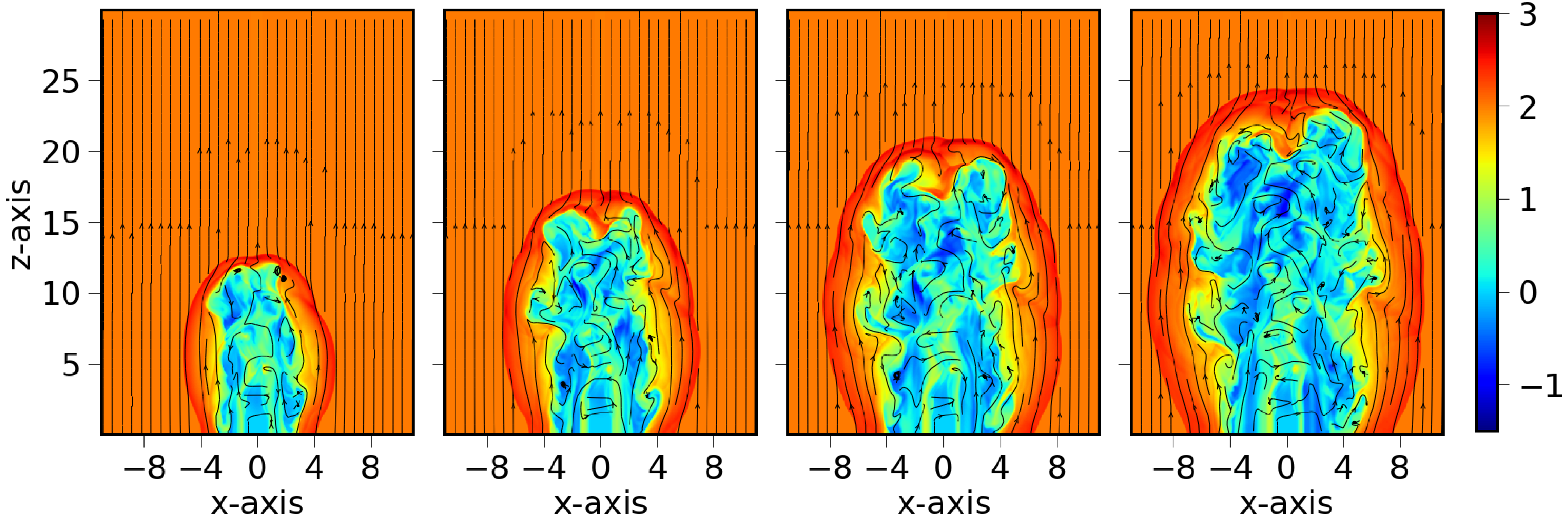
INNER BACK-FLOW

- Result of reflection from the jet head along the jet axis
- Goes away if the termination shock leaves the computational domain

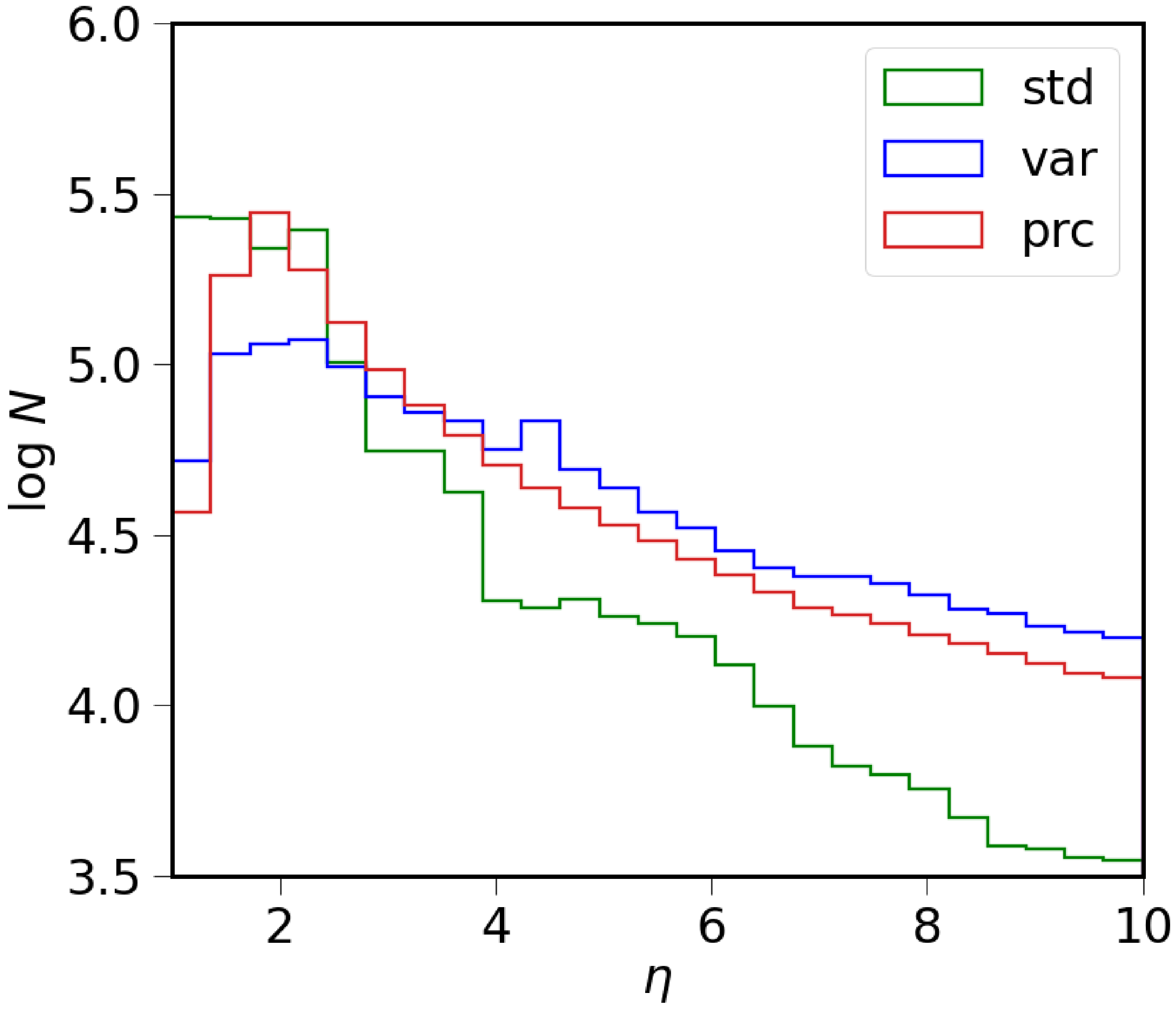
VARIABLE JET

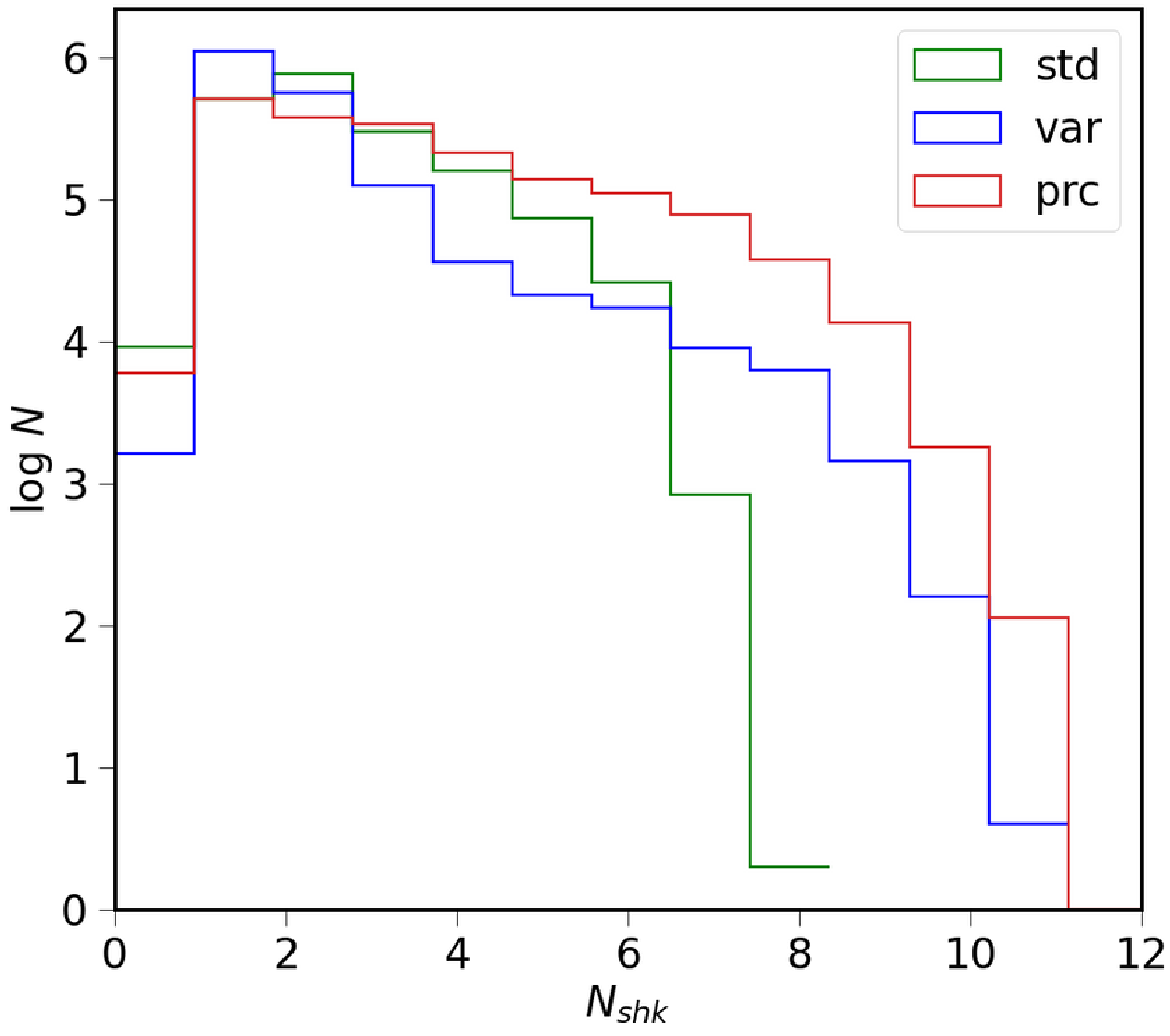


PRECESSING JET



SHOCKS

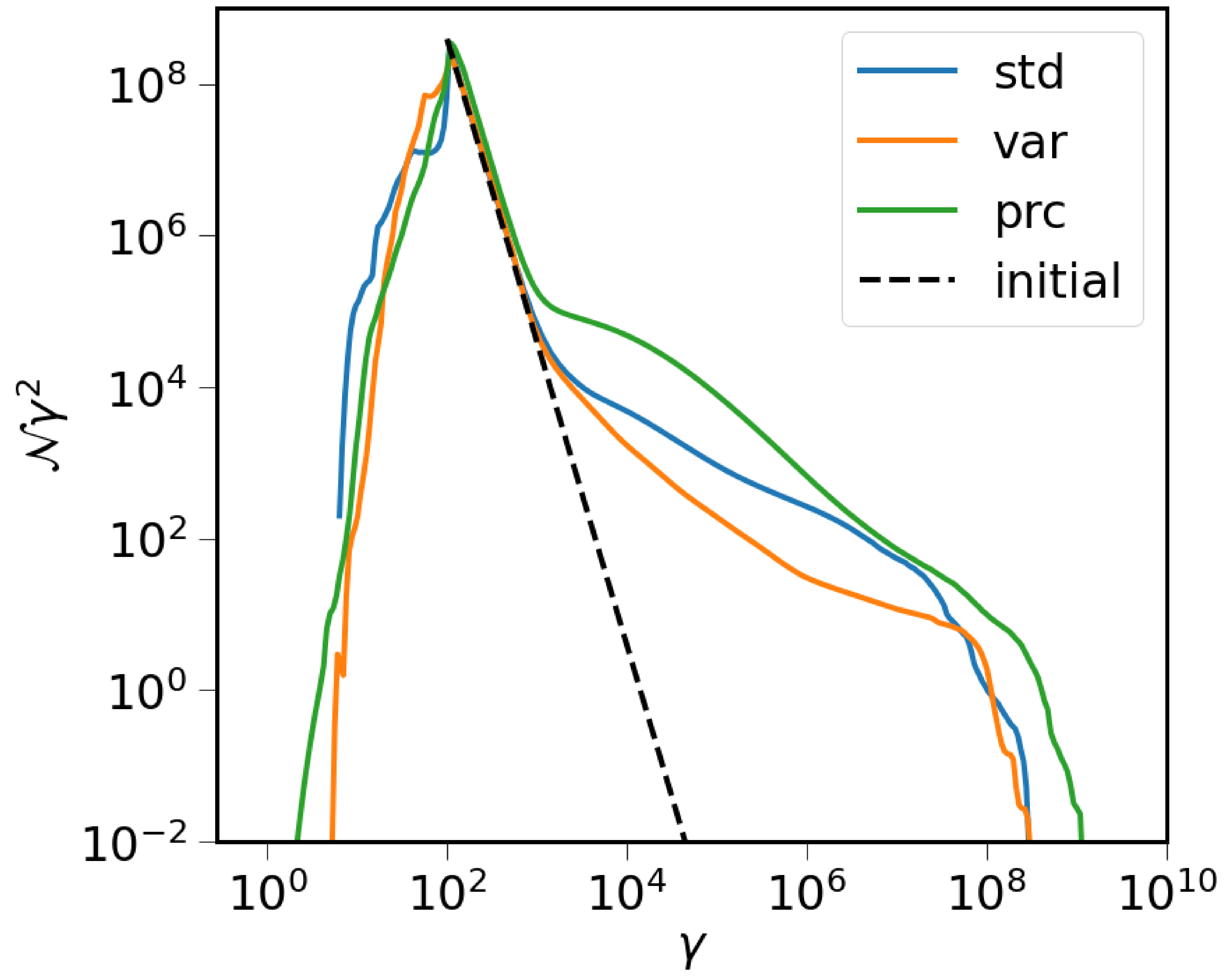




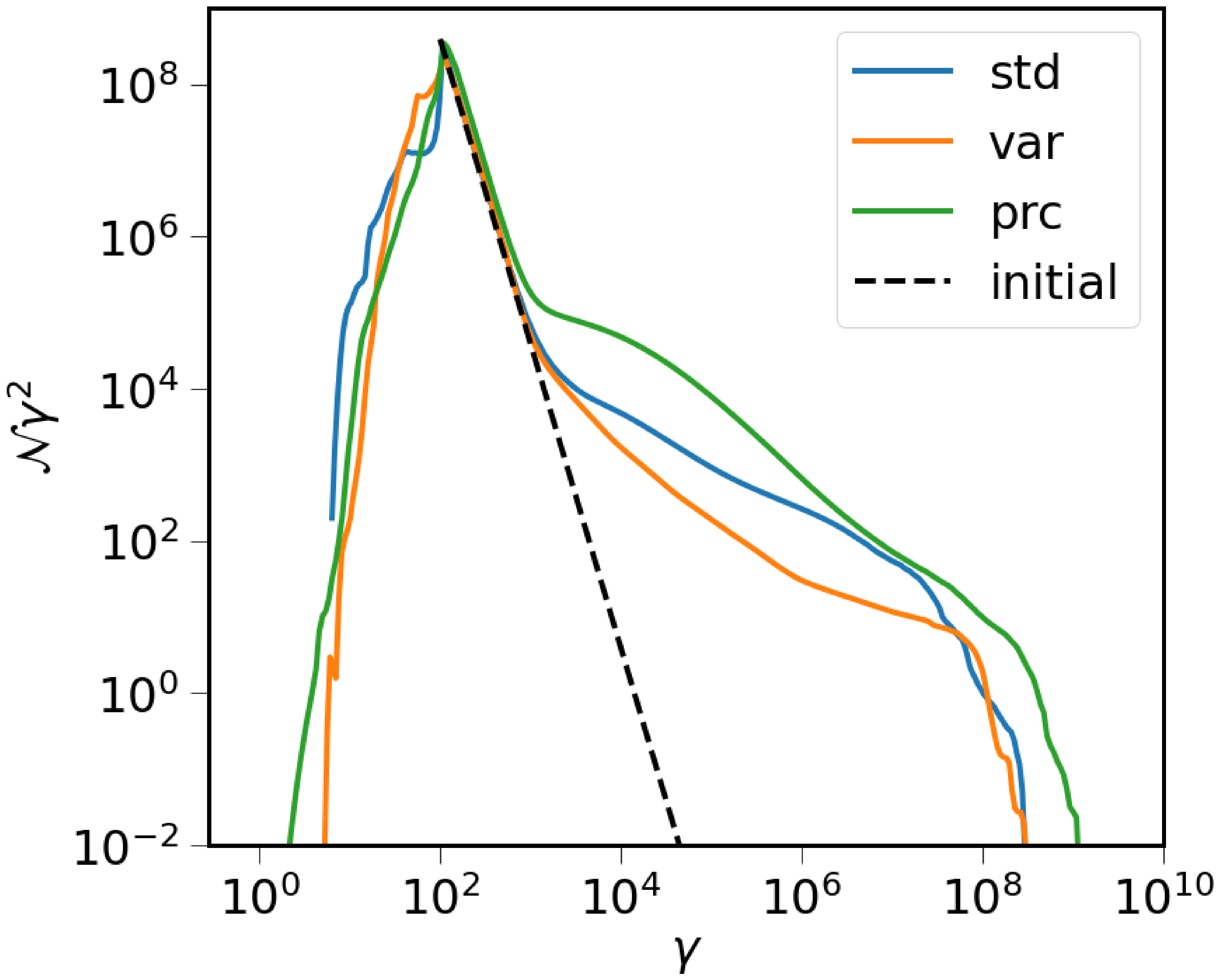
Compression Ratio

STRENGTH VS NUMBER

OVERALL SPECTRA

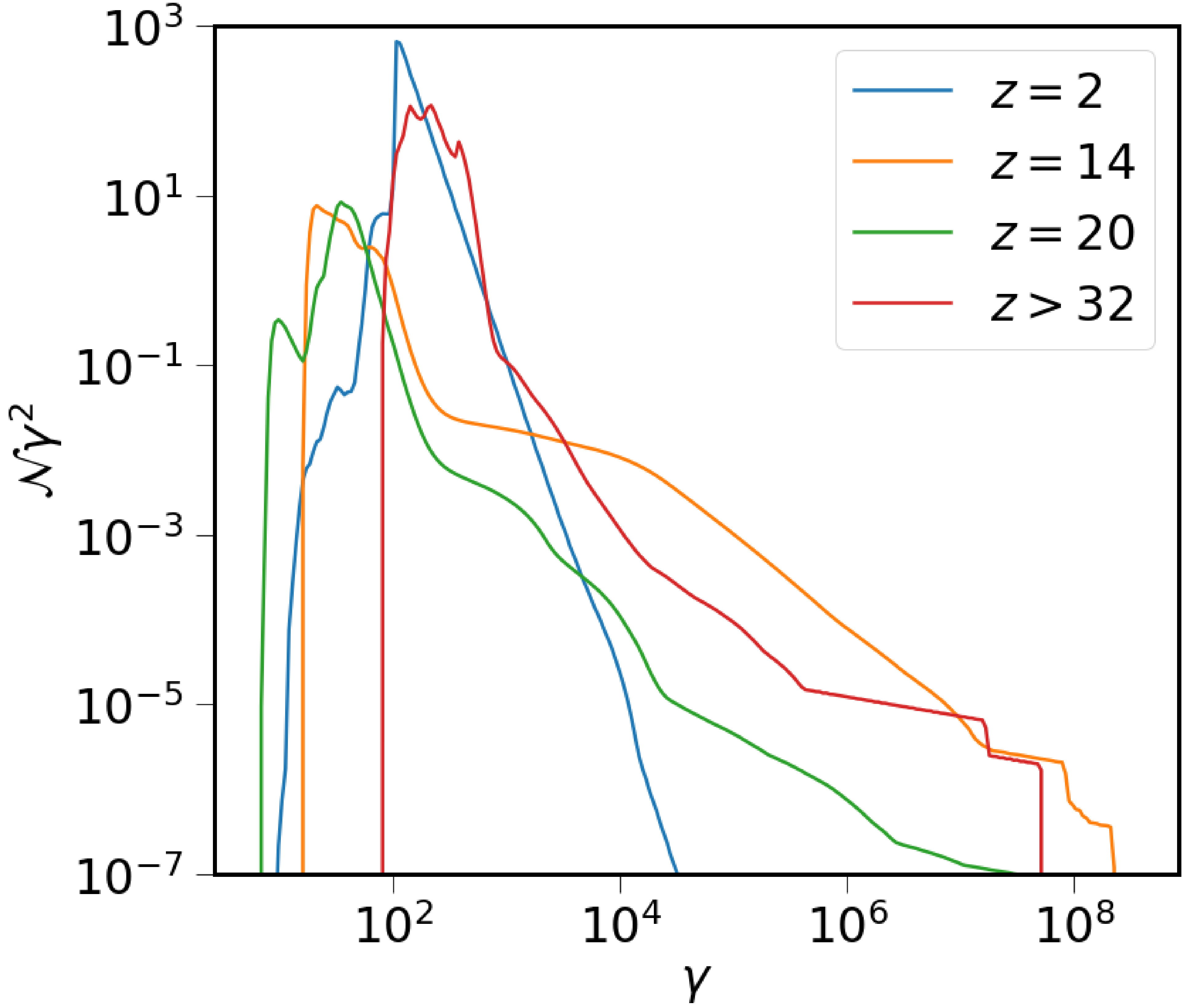


OVERALL SPECTRA



NUMBER OF SHOCKS MORE IMPORTANT THAN THE SHOCK STRENGTH FOR PARTICLE ACCELERATION

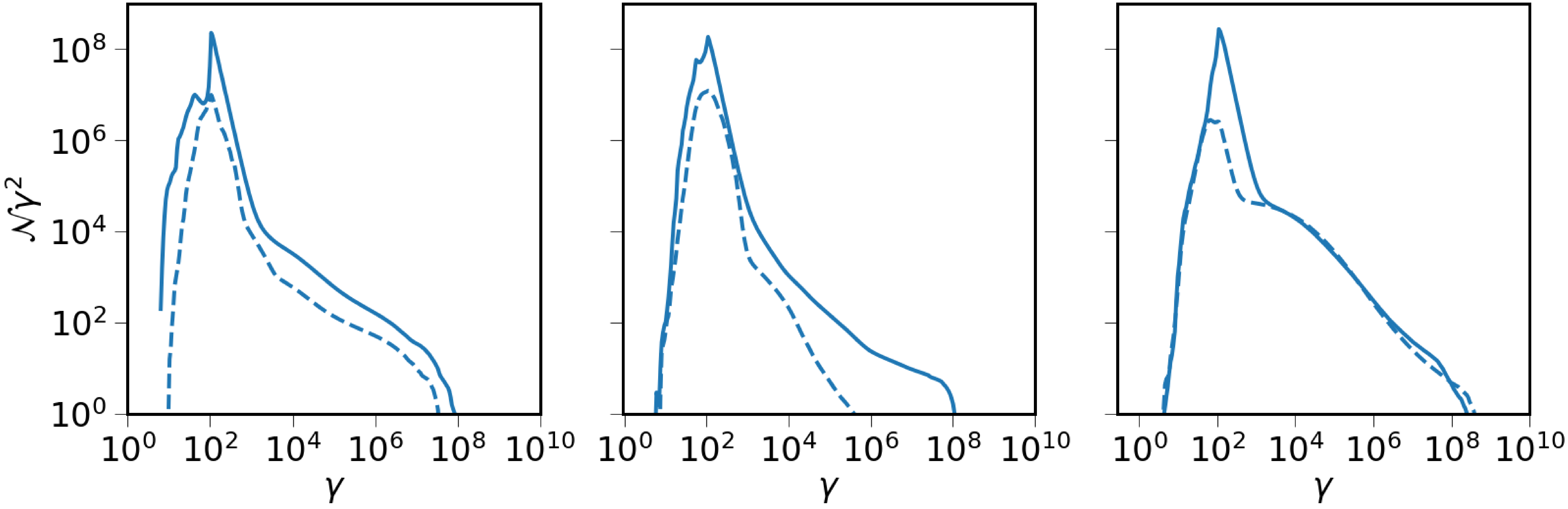
JET COMPONENTS



OUR STEADY SHOCK IS A SITE OF EFFICIENT ACCELERATION

JET VS ENTRAINED MATERIAL

Jet => tracer > 0.8
Entrained material => tracer < 0.8

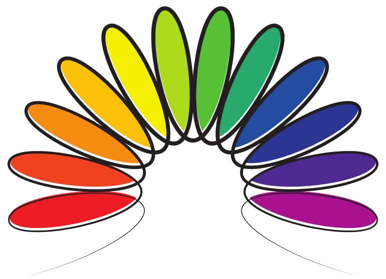


Steady Jet

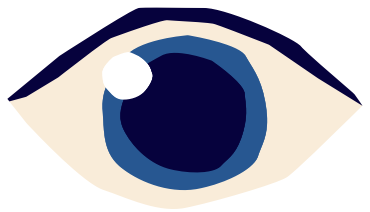
Variable Jet

Precessing Jet

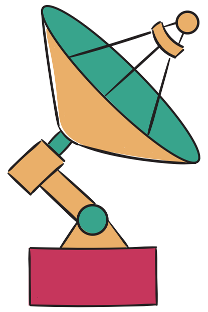
FUTURE PROSPECTS



Synthetic emission, spectral, polarization signatures



Projection Effects



Comparison with observations

CONCLUSION

TAKE HOME MESSAGES

1

Particle acceleration depends on jet injection nozzle

TAKE HOME MESSAGES

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2. Number of shocks more important than shock strength

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3. Our steady shock is a site of efficient particle acceleration

TAKE HOME MESSAGES

1. Particle acceleration depends on jet injection nozzle

2. Number of shocks more important than shock strength

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4. Precessing jet is the most efficient accelerator, followed by steady & variable jet

TAKE HOME MESSAGES

THANK YOU!

1. Particle acceleration depends on jet injection nozzle

2. Number of shocks more important than shock strength

3. Our steady shock is a site of efficient particle acceleration

4. Precessing jet is the most efficient accelerator, followed by steady & variable jet

5. Cocoon of precessing outflow is as efficient as jet in accelerating particles