Models of backflows emission from AGN jets

The role of the host environment.

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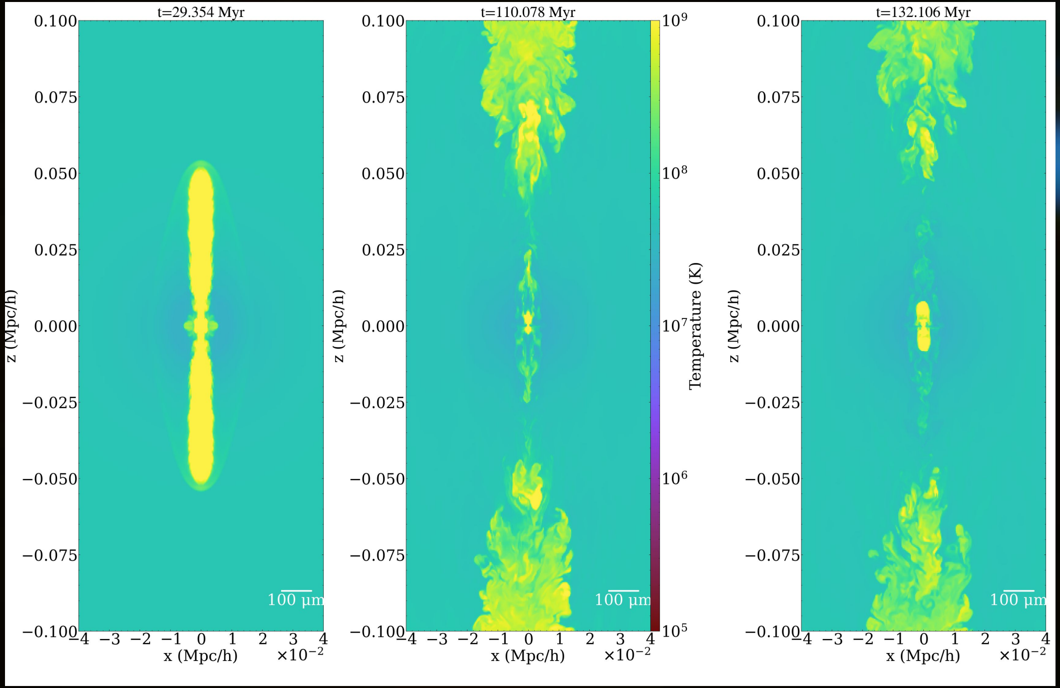
- AGN’s duty cycle: $\tau_{AGN} \ll \tau_{Hubble}$ → likely more than one episode of jet emission;
- ISM/IGM relaxation times: $\tau_{IGM} \simeq \tau_{Hubble}$ → jets after the first will propagate in a turbulent, non-equilibrium ISM/IGM;
- Questions:
  1) Does turbulence in the host ISM/IGM affect backflows and their feedback on the central Supermassive BH ?
  2) Can we detect and measure backflows in Blazars and CSS/GPS?

Backflows in radio lobes can be detected through polarization measurements. (Laing & Bridle, 2012, more later).

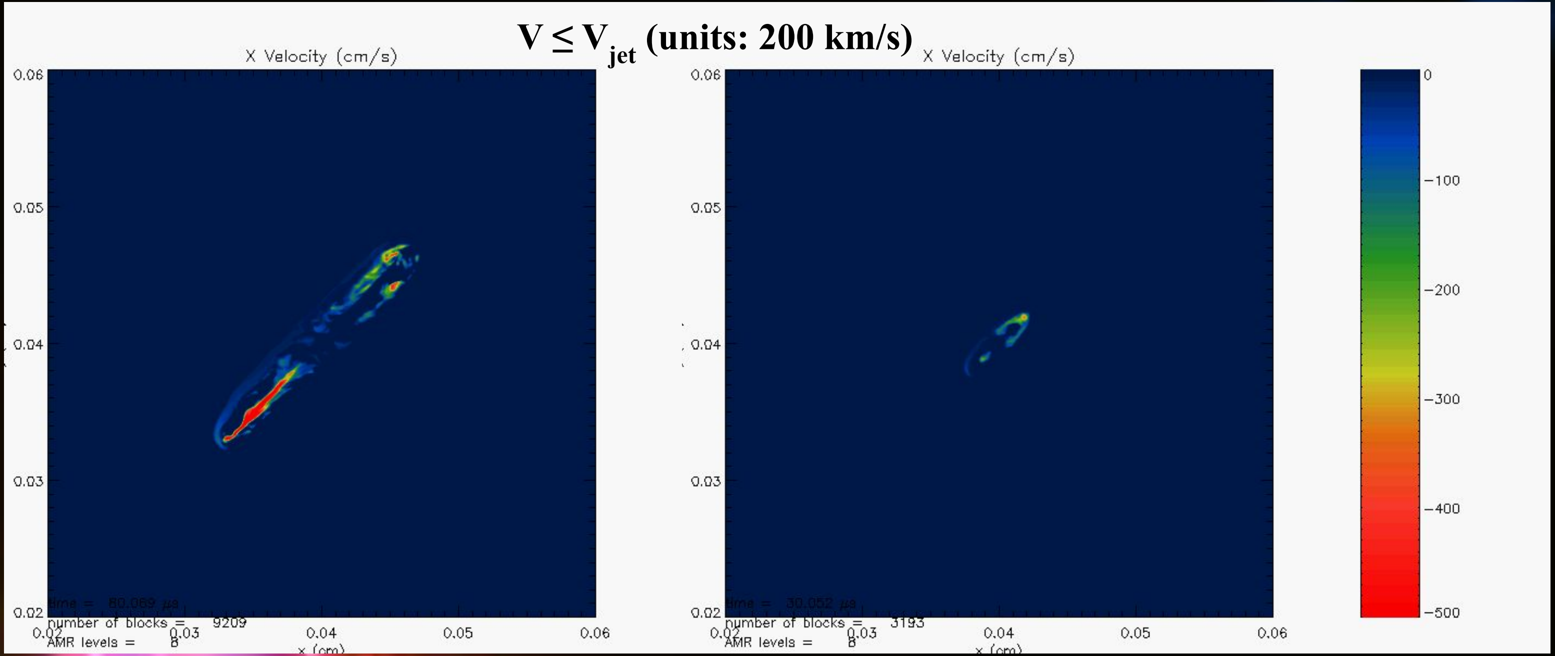
Matthews et al. (2019) suggest that the secondary shocks arising along the backflows are good accelerators of charged particles up to GeV energies.



We have started a series of *numerical experiments* to understand the *hydrodynamic processes* underlying the generation and support of backflows under **realistic** cosmological conditions (Cielo et al, 2017, 2018a, 2018b):

- Multiple jet episodes, random injection angles;
- Realistic cooling function (down to *T~10 K*);
- AMR (FLASH), sub-pc res.

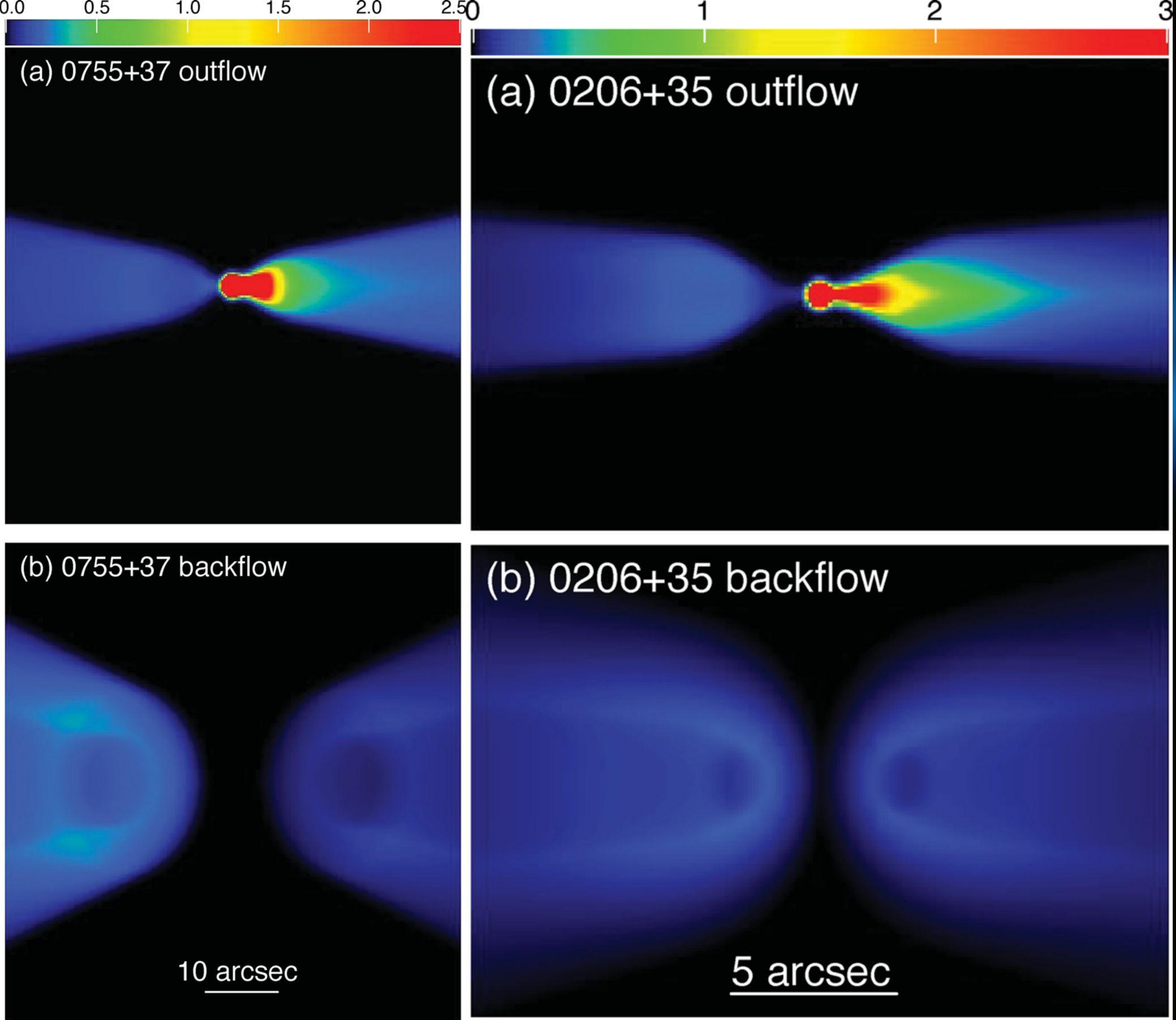
Backflows are easily detected in numerical experiments of jet/cocoon systems propagating in inhomogeneous, isothermal ISM/IGM.



Main features:

a) *Large-scale structure* from the **Hotspot** (kpc) down to the accreting region (sub-pc);

b) *Backflows' ram pressure* affects the accr. disk → enhances P_{jet} (more later).



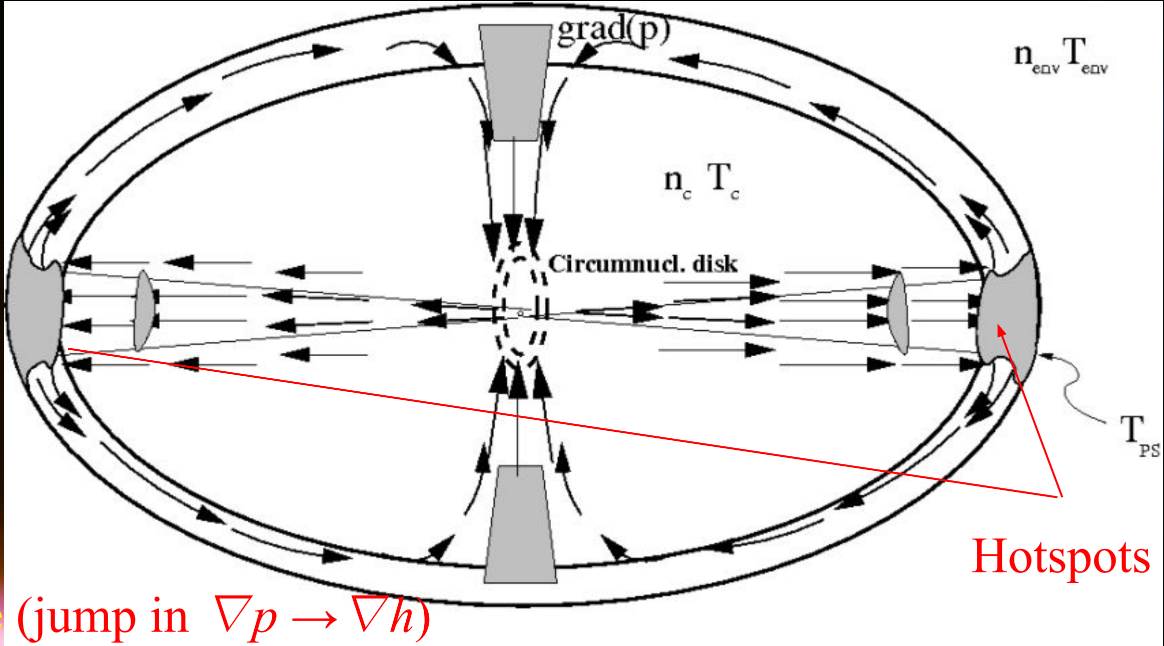
Numerical findings show BF's morphologies consistent with observations of two FRI sources (Laing and Bridle, 2012)

What is the physical significance of backflows?

Why we want to detect and measure them?

→ A 3D hydrodynamic model satisfactorily answers both questions (Cielo et al., 2018)

Backflows↔ **Crocco theorem**: $\vec{v} \times \mathrm{curl}\,\vec{v} = \nabla h - T\nabla S$

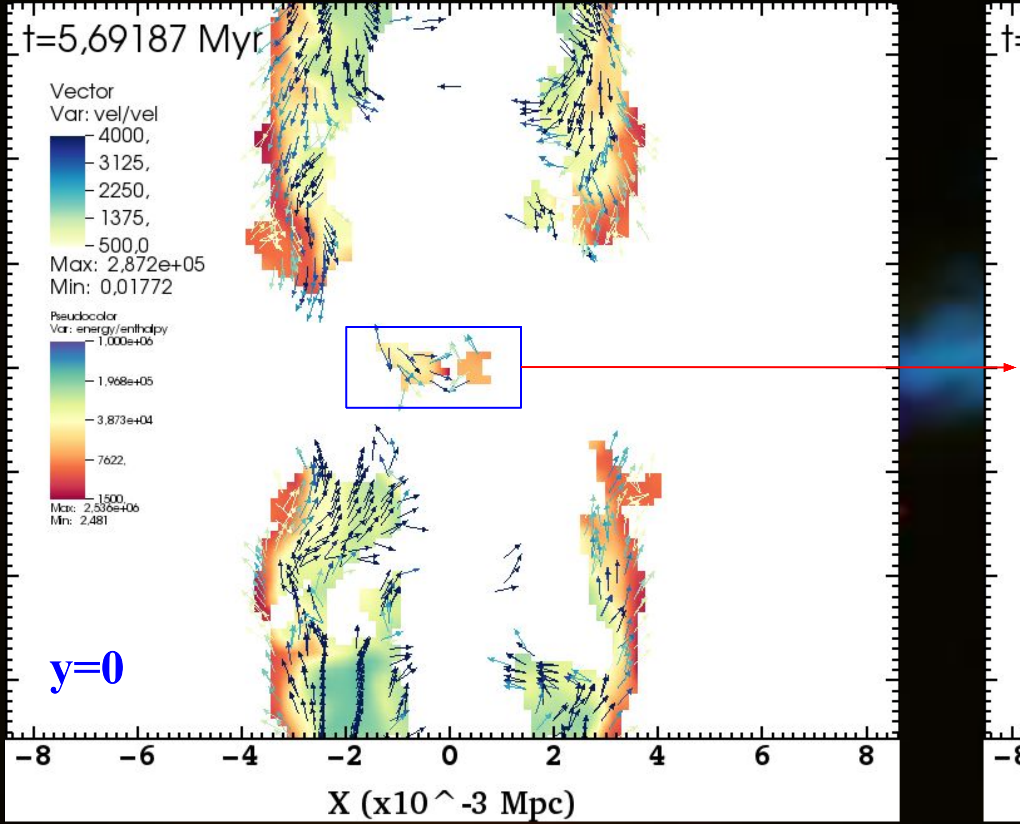


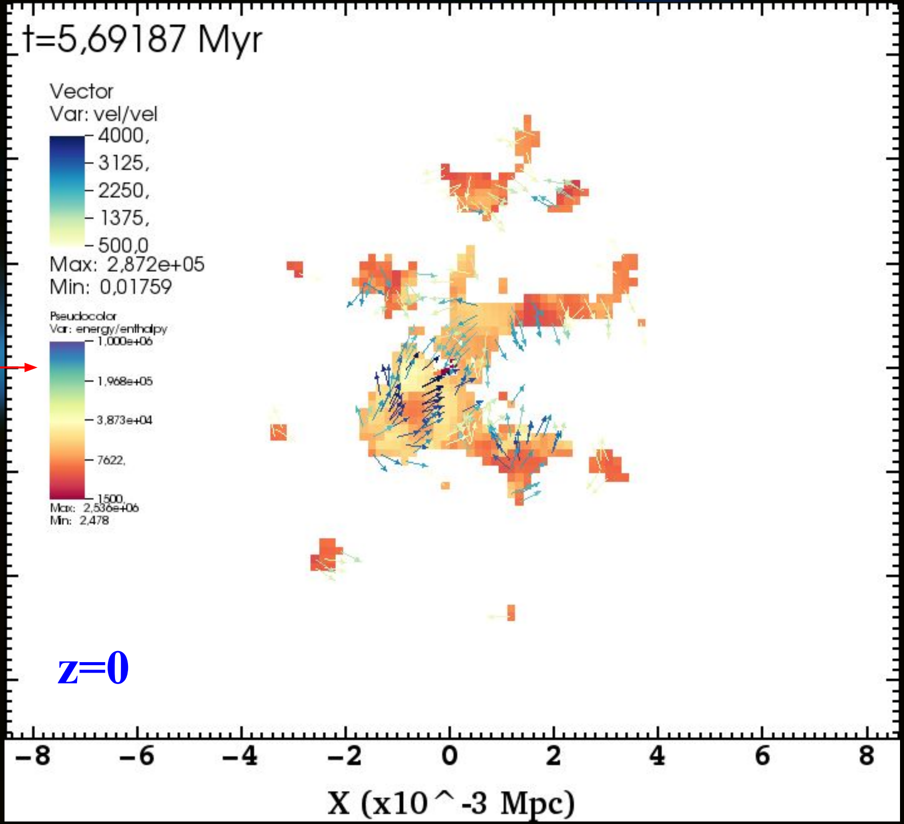
Hotspots (jump in ∇S)

Mer. plane (jump in $\nabla p \rightarrow \nabla h$)

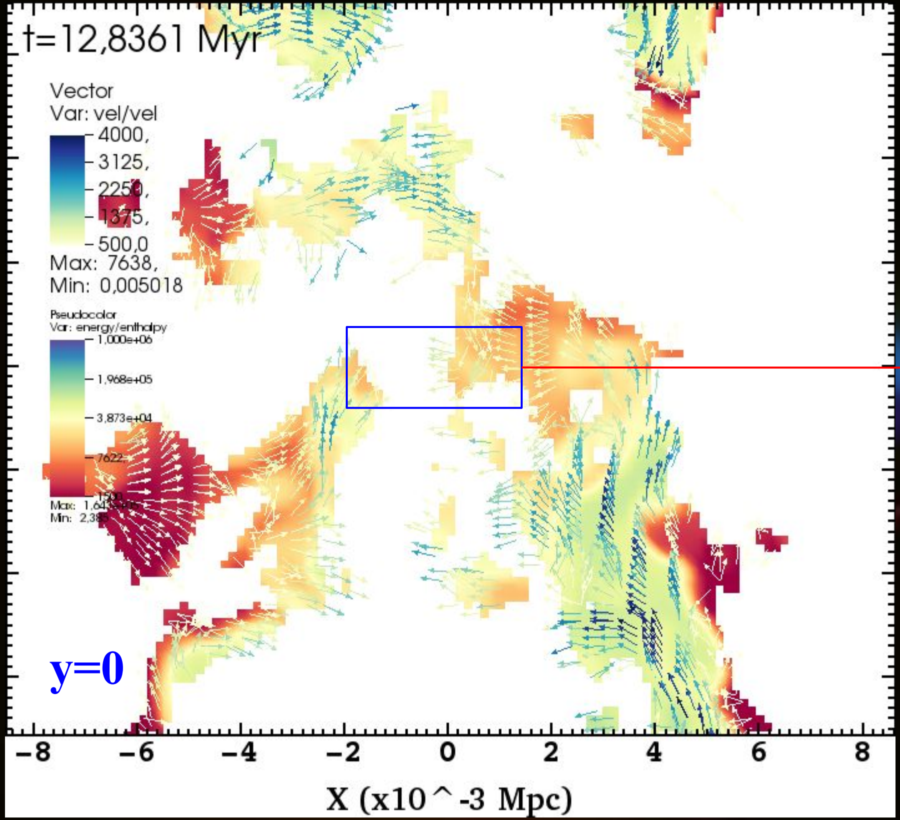
Backflows drive gas down to the accretion region ⟶ feedback : compresseses the accretion region and affects jet emission.

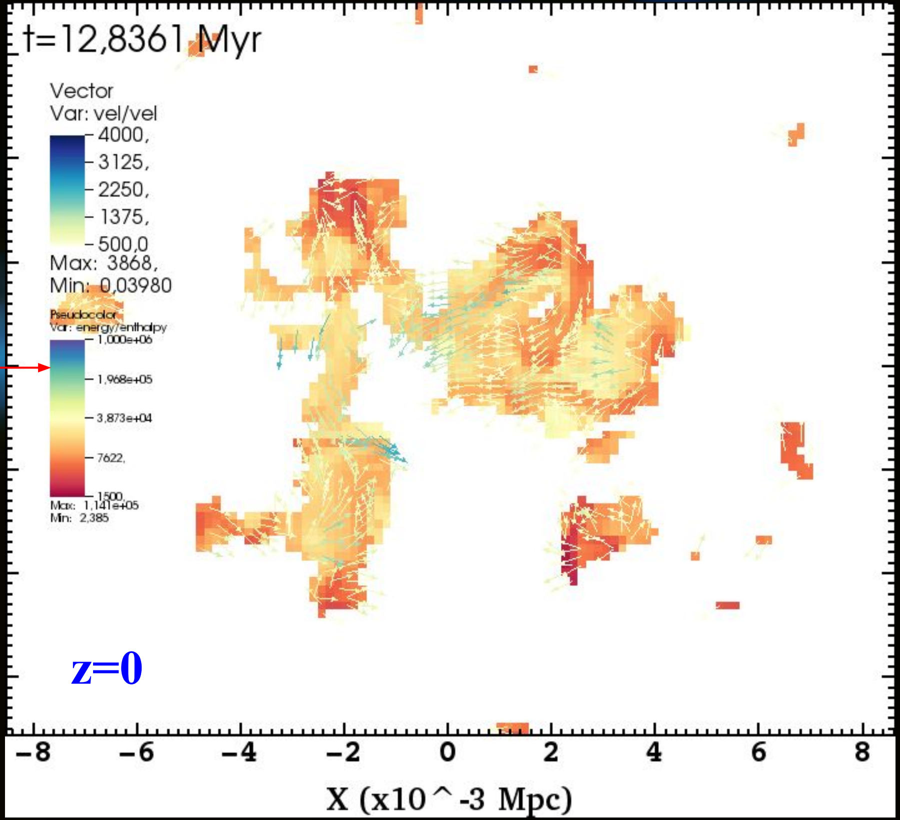
Feedback from backflows - $t_{jet} \sim 5.7$ Myrs



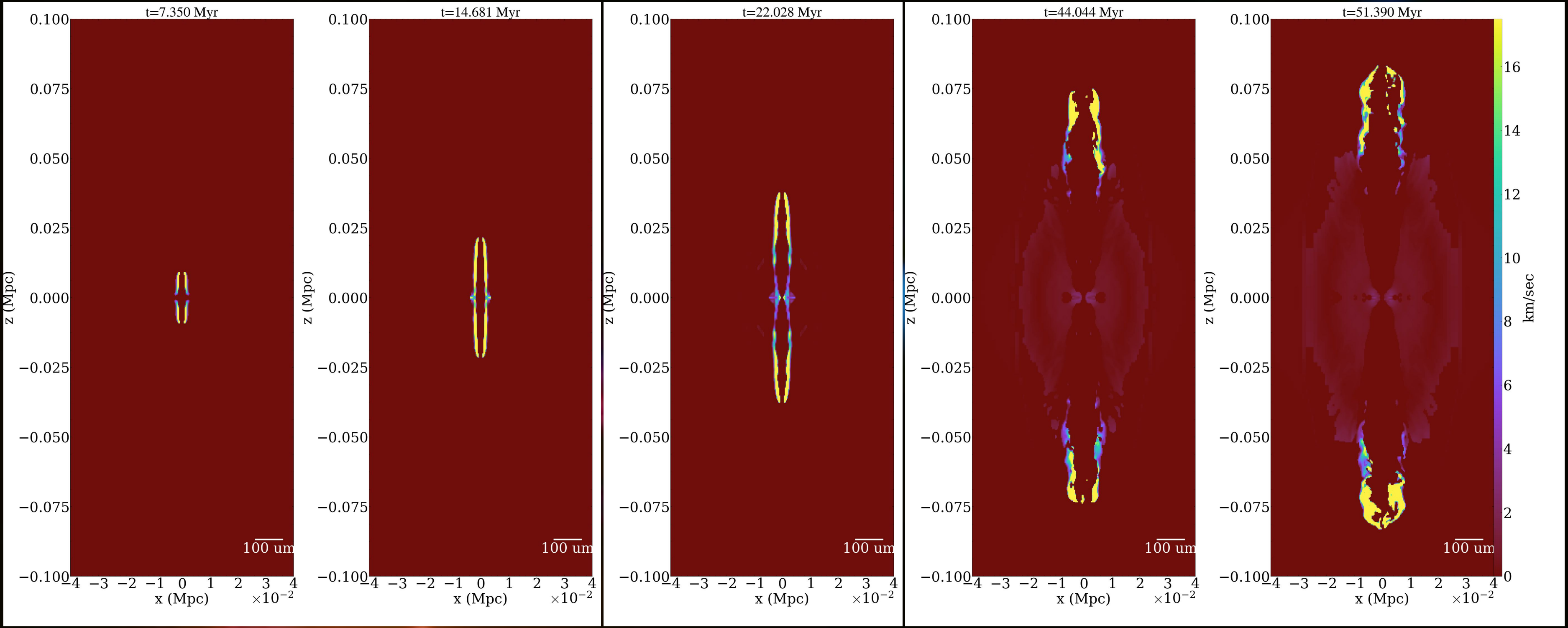


Feedback from backflows - t_{jet} ~ 12.84 Myrs



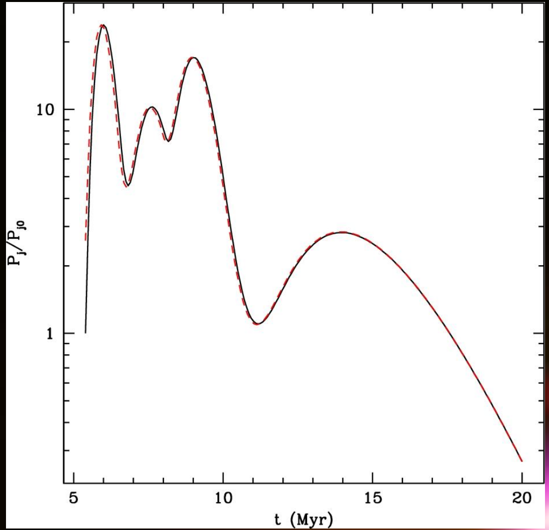


Backflows die off when they lag behind the jet: $|v_{jet}| \gtrsim |v_{bck}|$

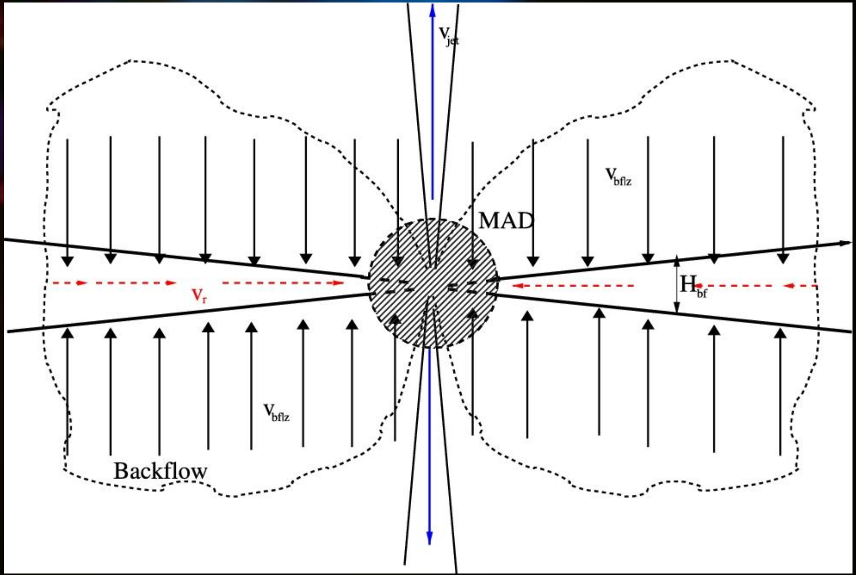


t=3.18 14.68 32.07 44.06 51.19 (Myrs)

Enhancement of jet's power



Assuming that jets are generated through the MAD/Blandford-Znajek MHD process: $P_{jet} \propto B^2\omega^2$ and B will be enhanced by the frozen components driven by the backflow accreting plasma.



<u>NOTE</u>: From this model the timescale for P_{jet} enhancement $\tau_{jet} \simeq$ 20 Myrs, comparable with the measured active phase τ_{AGN} (Shabala et al., 2018).

Backflows are *coherent* large-scale flows within radio lobes → can be detected through *polarization measurements* in Blazars

They disappear when jets/cocoon propagate in a highly turbulent medium → probes of the underlying ISM/IGM.

A systematic study with SKA will allow a *systematic* identification of backflows up to z~0.7, and look for correlations with *γ-ray* emission and with jet's power. Both are predicted by models presented.

Backflows are a proxy for a *feedback mechanism*: the enhanced P_{jet} due to feedback will increase v_{jet} and ultimately detach the backflow from the accretion region.

The AGNs duty cycle timescale $\tau_{\mathrm{jet}} \simeq 20$ Myrs arises naturally, and it is mainly determined by the ratio π_{jet}/p_{ISM} between $\pi_{jet}=\rho v_{jet}^{2}$ and the ambient ISM pressure at injection.

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