Growth of a Localized Seed Magnetic Field in a Turbulent Medium

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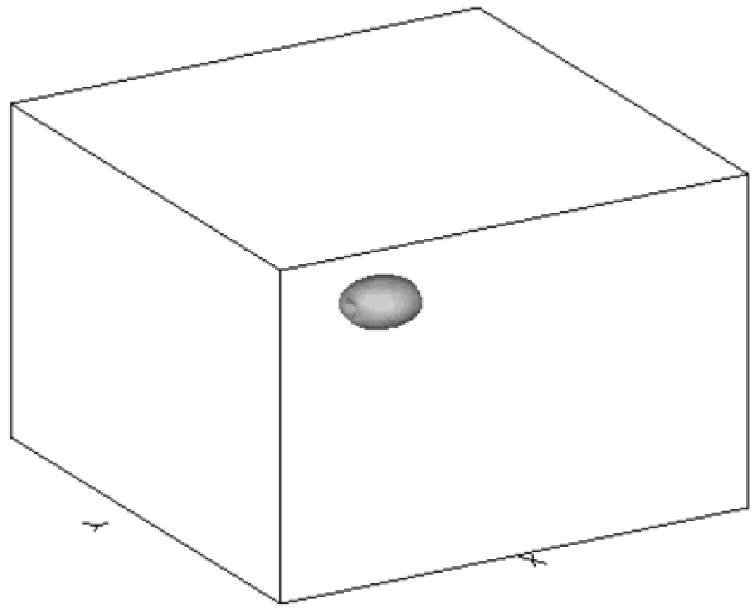
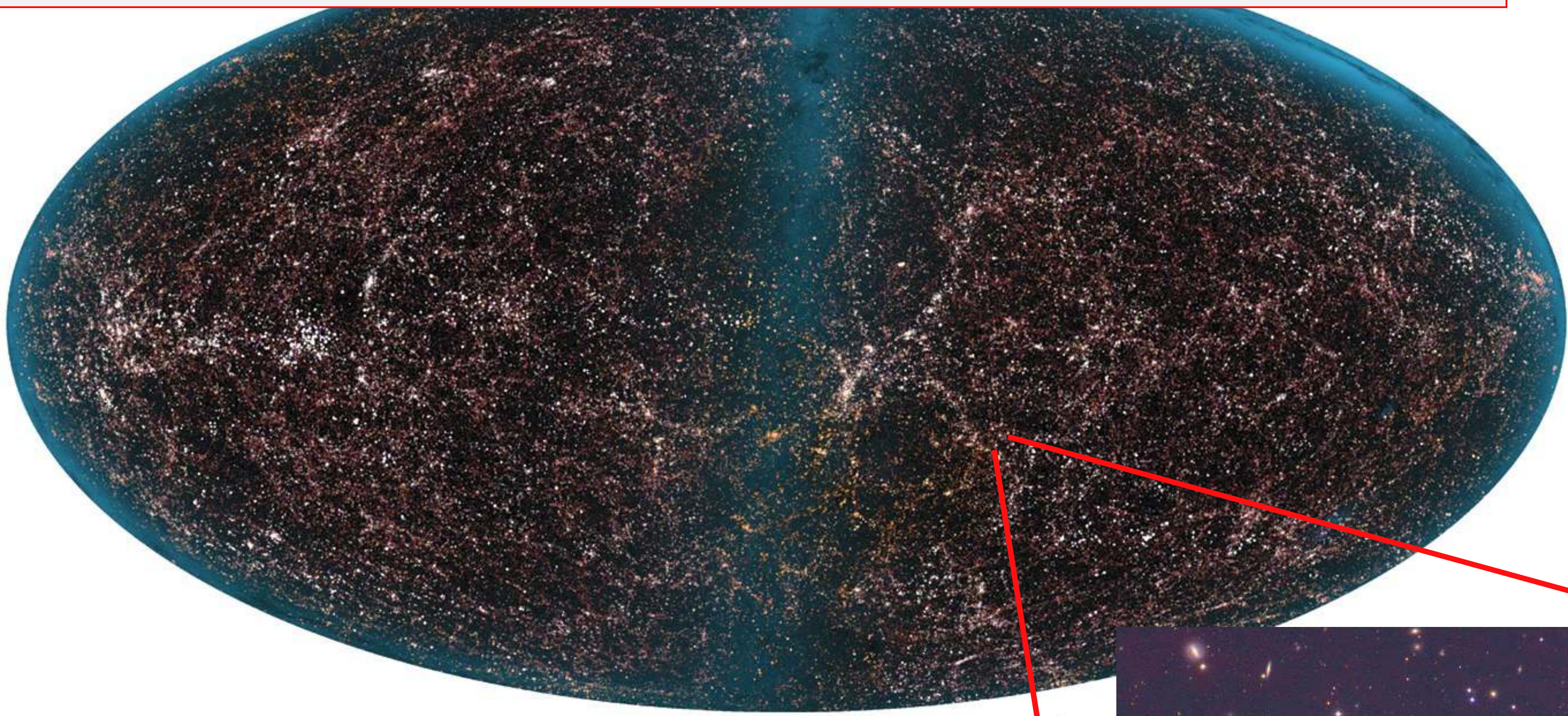
Ryu+(2008)
Cho (+Ryu) et al. (2009)
Cho & Yoo (2012; ApJ, submitted)
Cho (2012; in preparation)



Turbulence plays important roles in origin of cosmic B



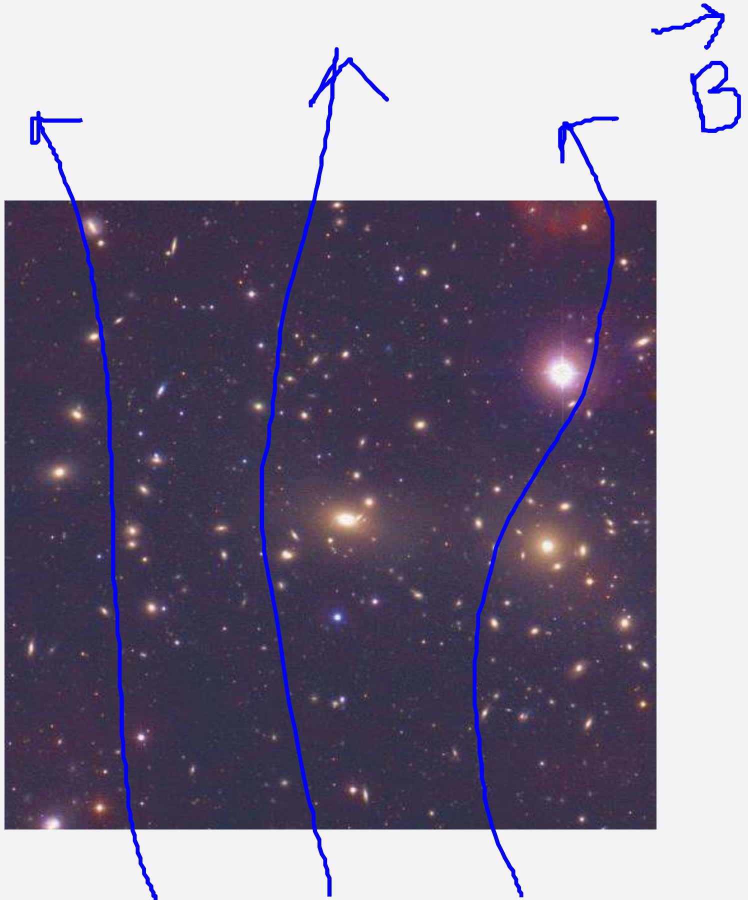
Distribution of Nearby Galaxies
(2Micron All Sky Survey)

Weak seed field → Strong B

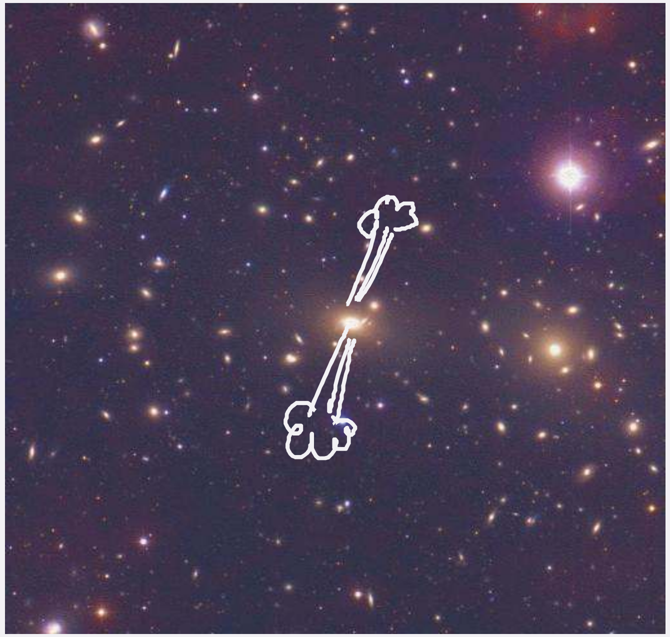
↑

Turbulence

Origin of cosmic seed magnetic fields is uncertain.



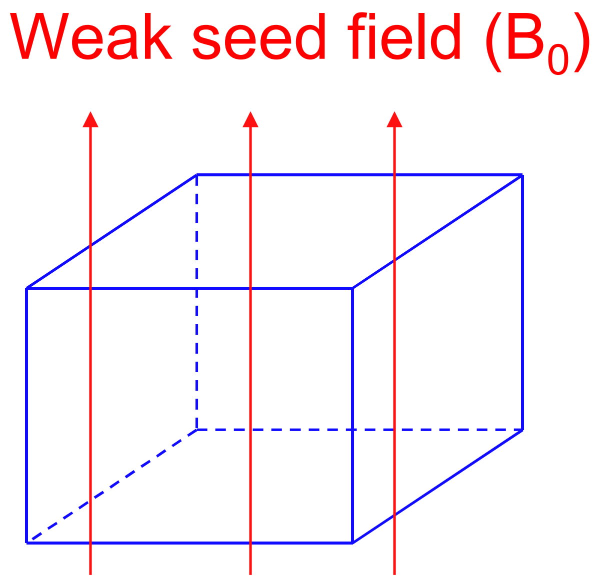
Cosmological?



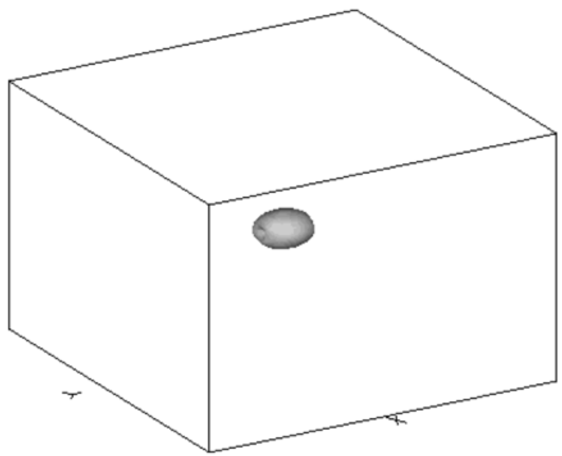
Astrophysical?

Plan

-Uniform seed field case

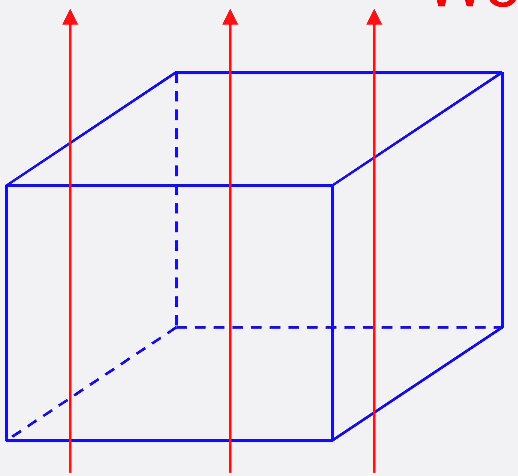


-Localized seed field case

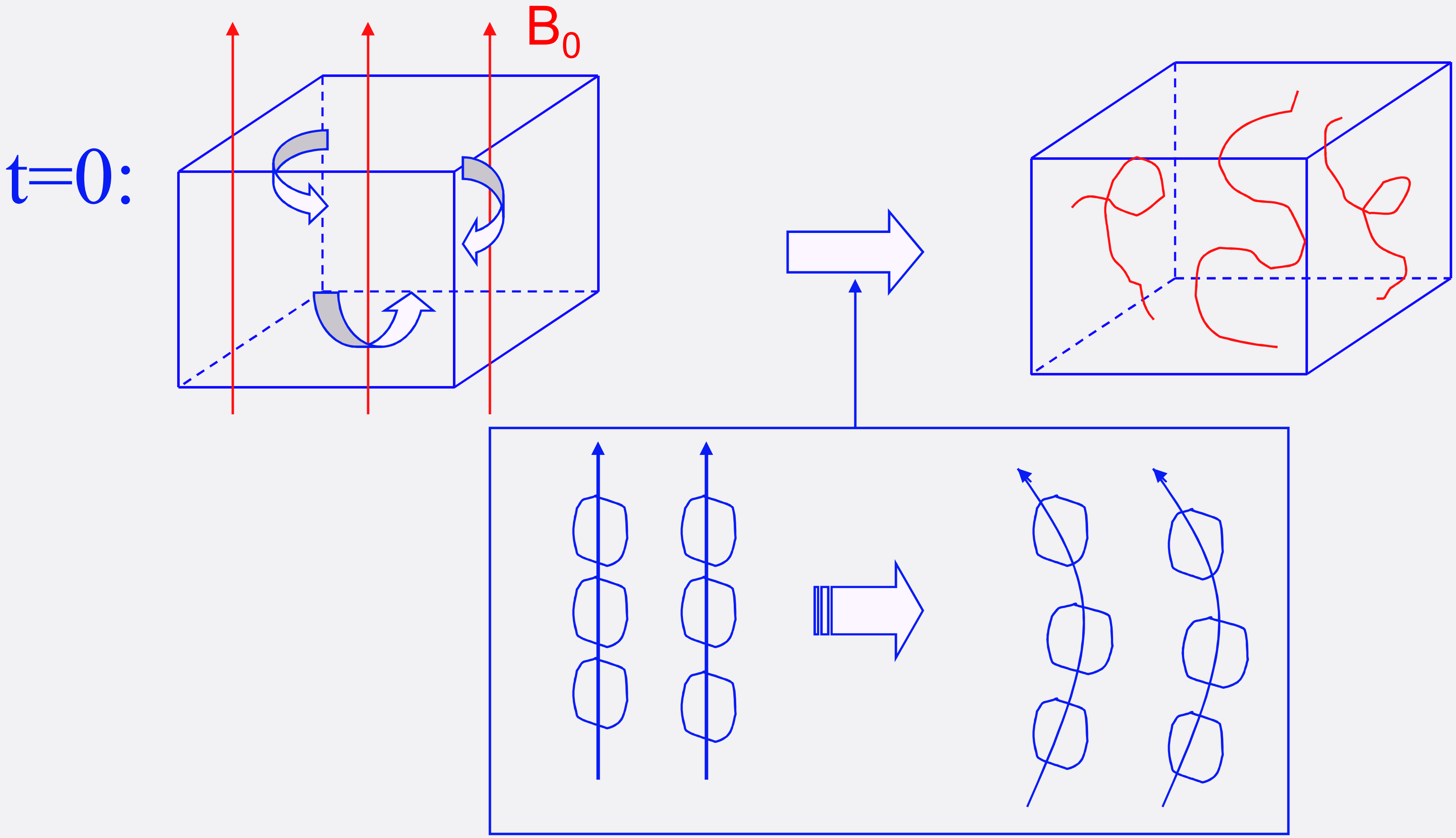


Topic 1. Amplification of a uniform seed field in turbulence

- How can MHD turbulence amplify B fields?



Stretching of field lines

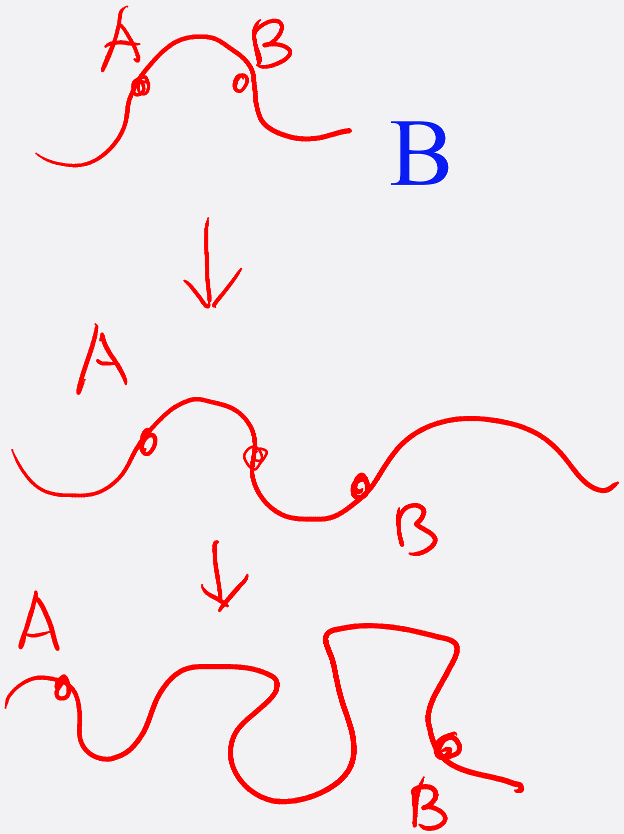


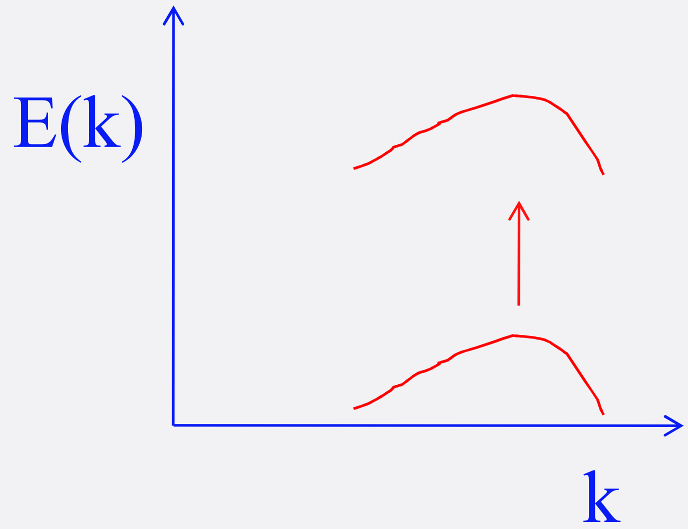
Fluid elements and field lines move together

*Back reactions are negligible if $E_{mag}<E_{kin}$

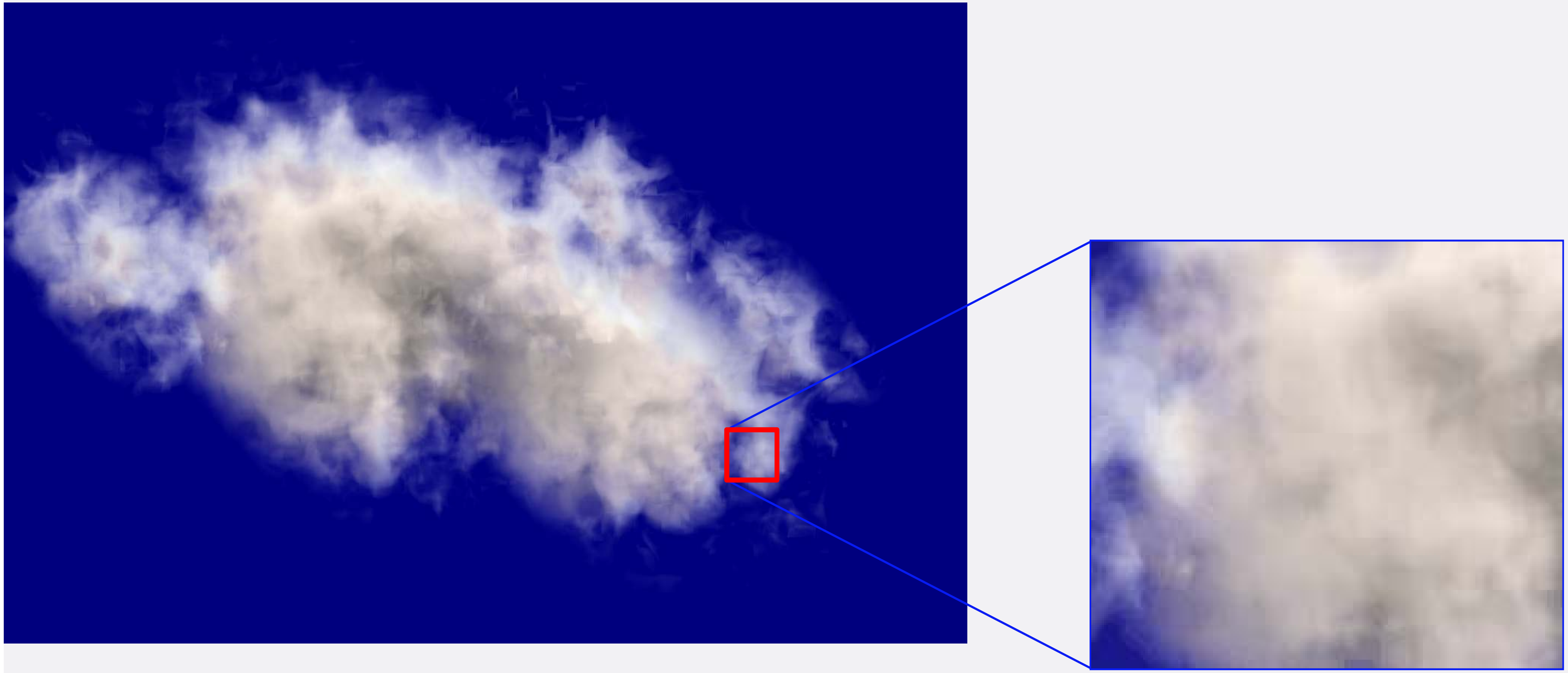
Expectations:

Stretching on the dissipation scale will occur first because eddy turnover time is shortest there



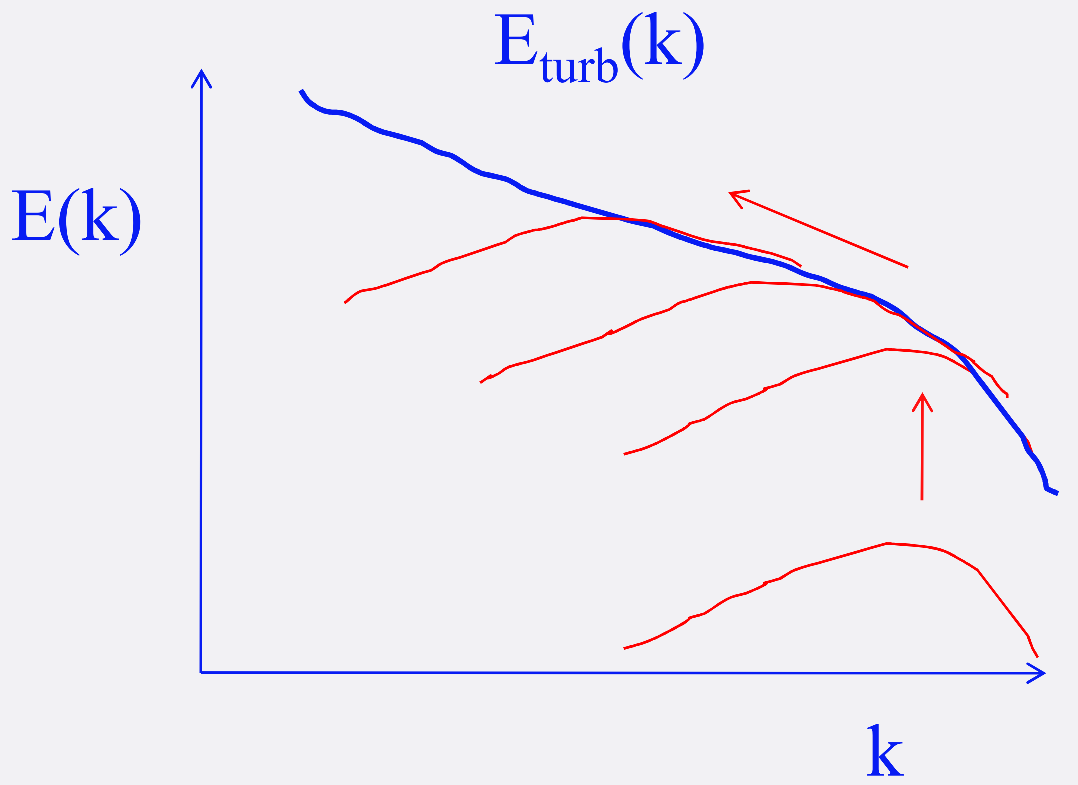


Exponential growth
(Batchelor 1950)



Small-scale structures change faster

Expectations:



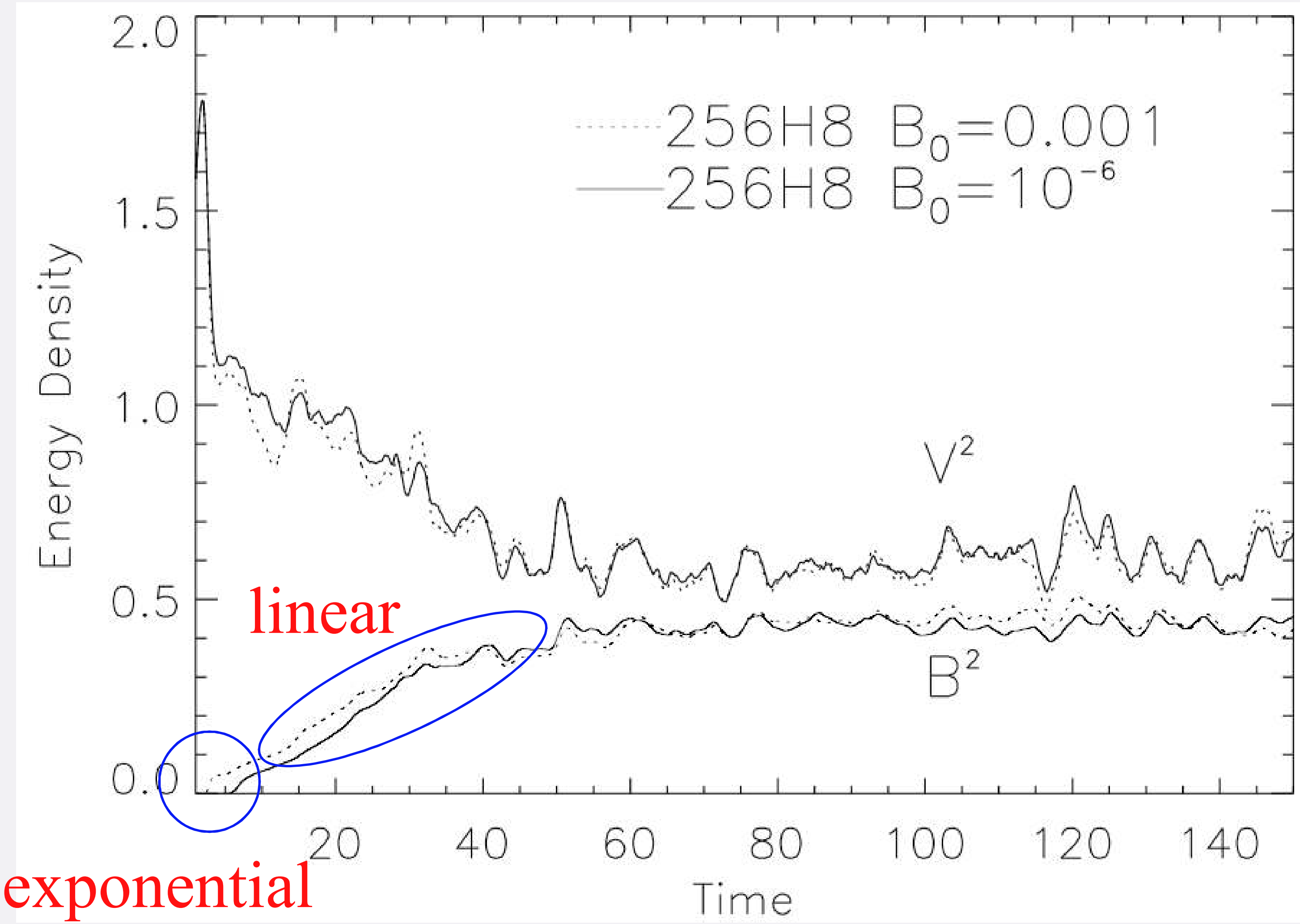
What will happen when $E_{turb} \sim E_{mag}$ on the dissipation scale?

➔ Exponential growth stage will end!

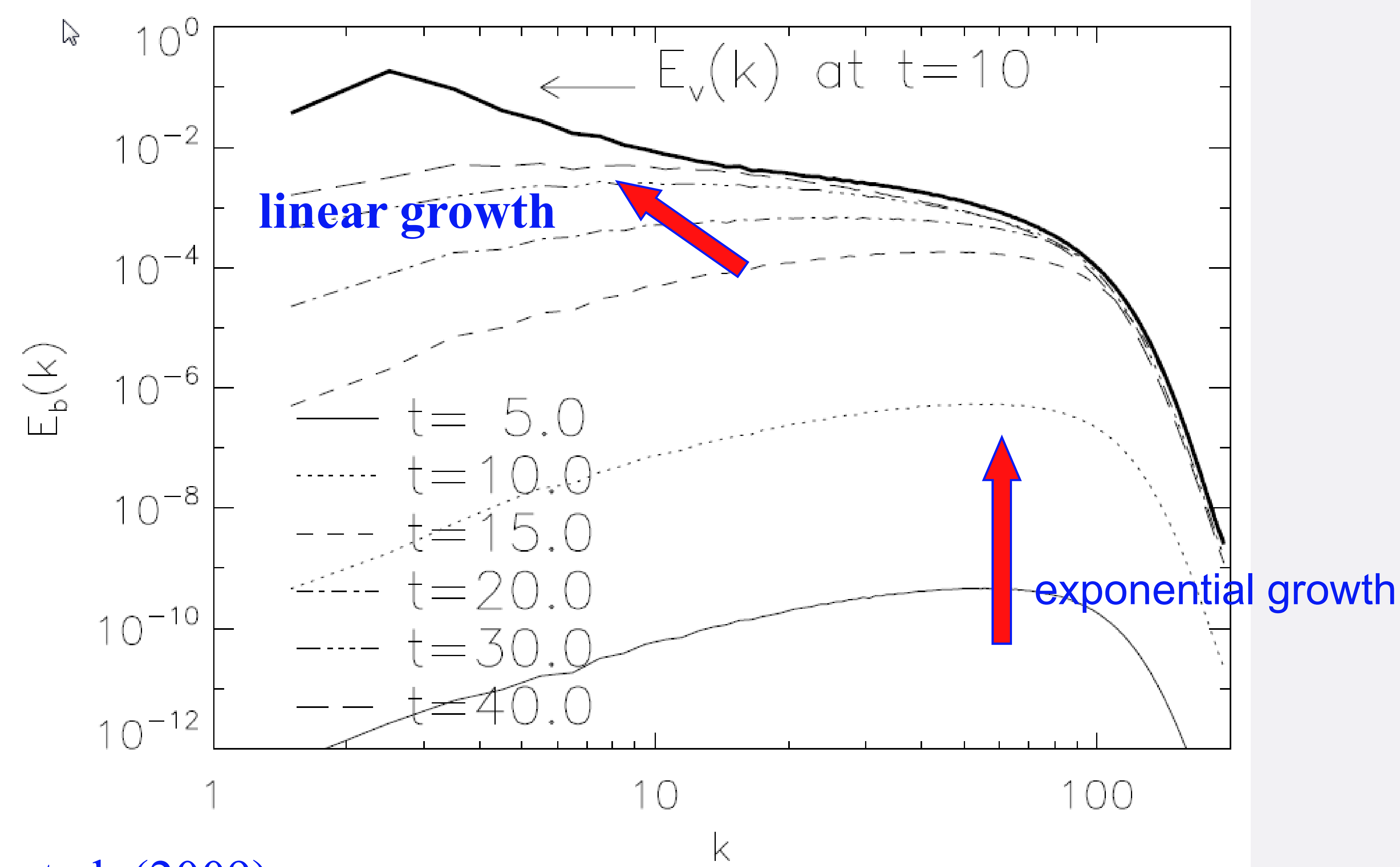
➔ Stretching scale gradually moves to larger scales.

(see, for example, Cho & Vishniac 2000)

Results of simulations



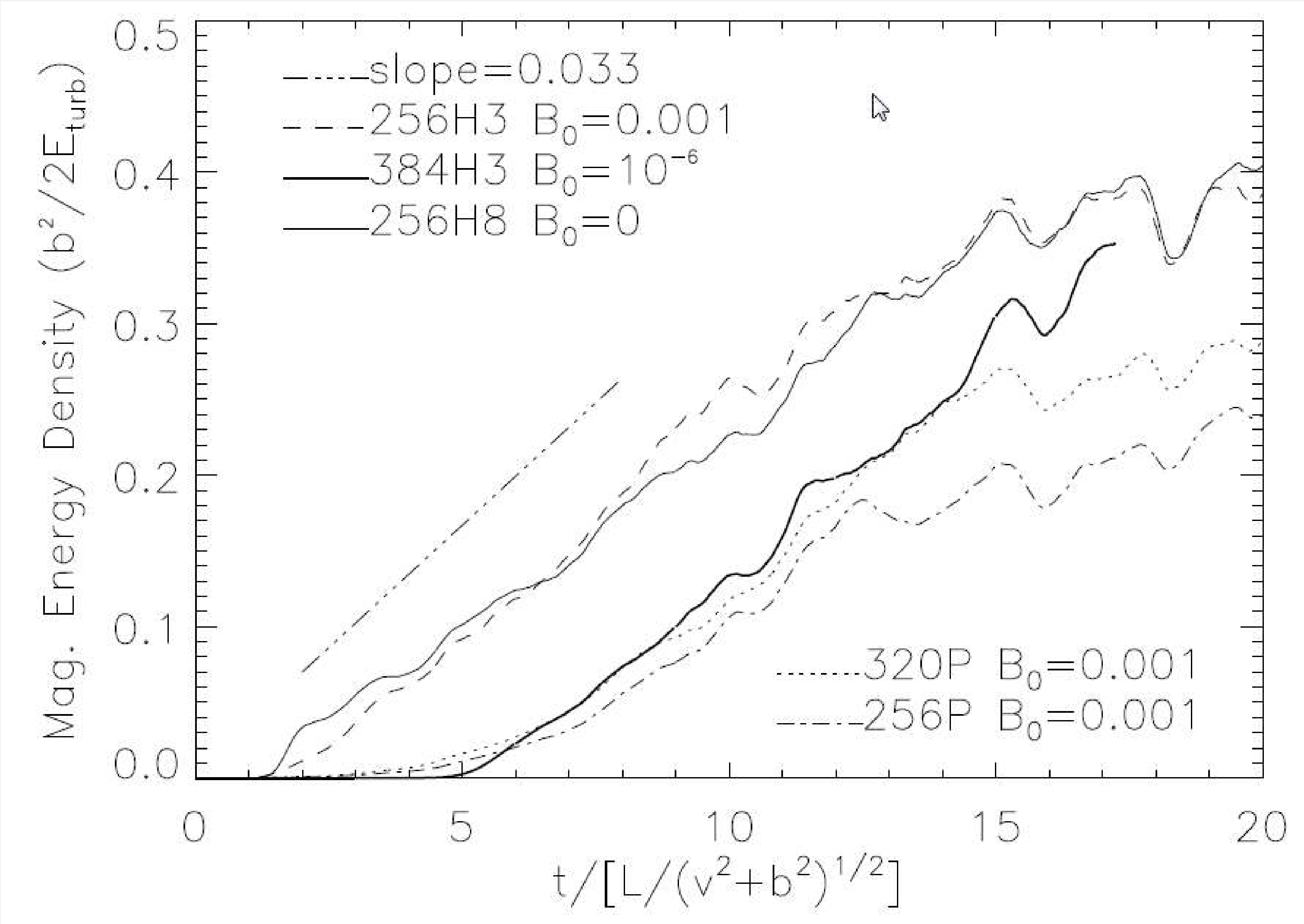
Ryu+2008; Cho, Vishniac, Beresnyak, Lazarian, Ryu (2009);
see also Schekochihin et. al. (2006)



Cho et al. (2009)

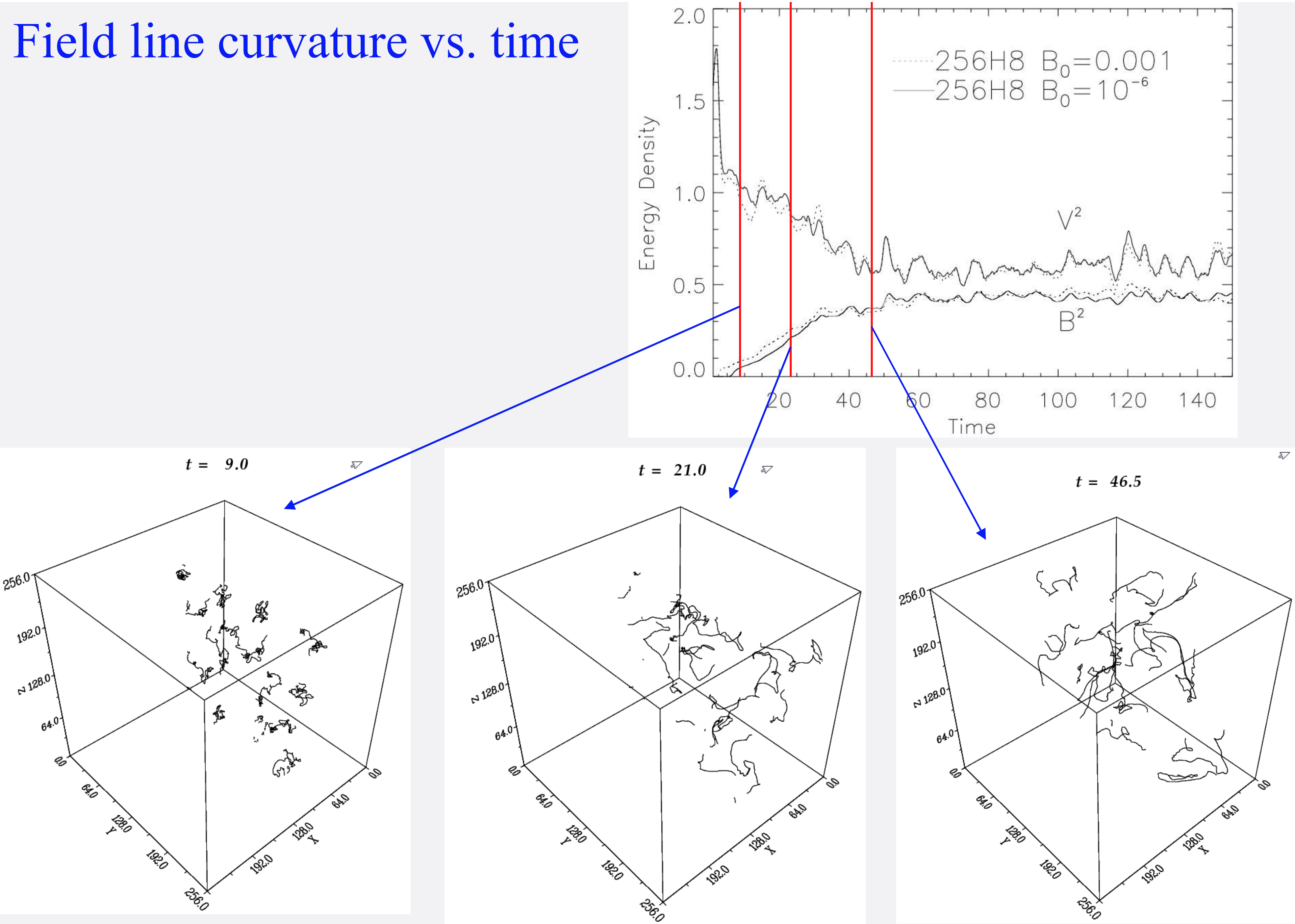
* See also Schekochihin et al (2006); Cho & Vishniac (2000)

The growth rate seems to be universal



Cho et al (2009)

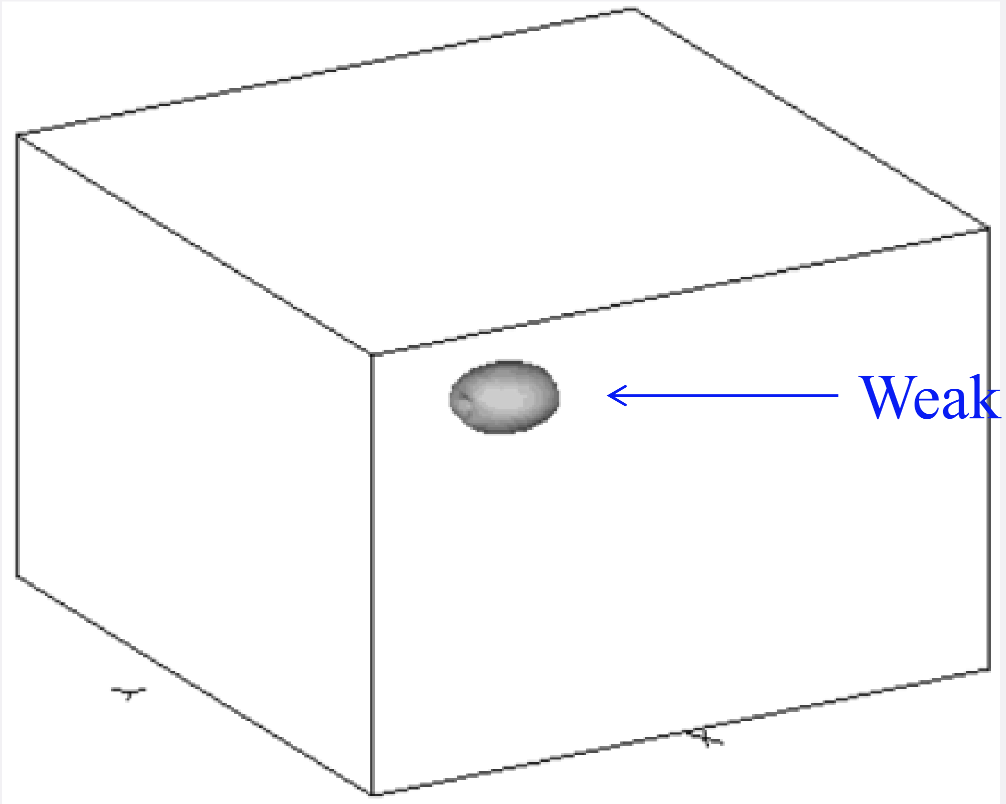
Field line curvature vs. time



Conclusions for Topic 1

-Turbulence can amplify uniform weak seed B fields
-Two stages of amplification: exp. and linear

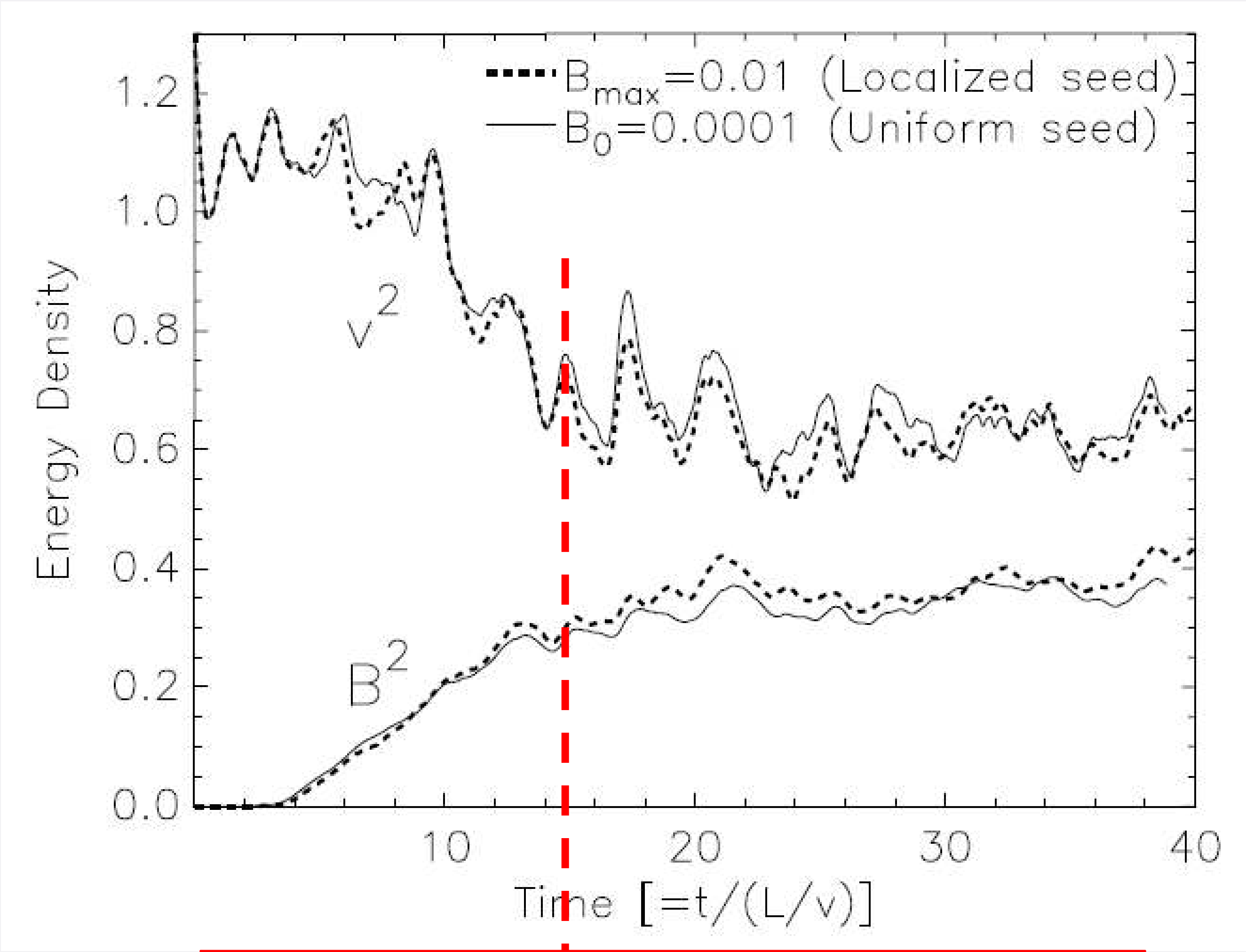
Topic 2: Growth of a localized seed field in turbulence



Assumption: driving scale (L) ~ box size (L_{sys})

(Actually, $L \sim L_{sys}/2.5$ in our simulations)

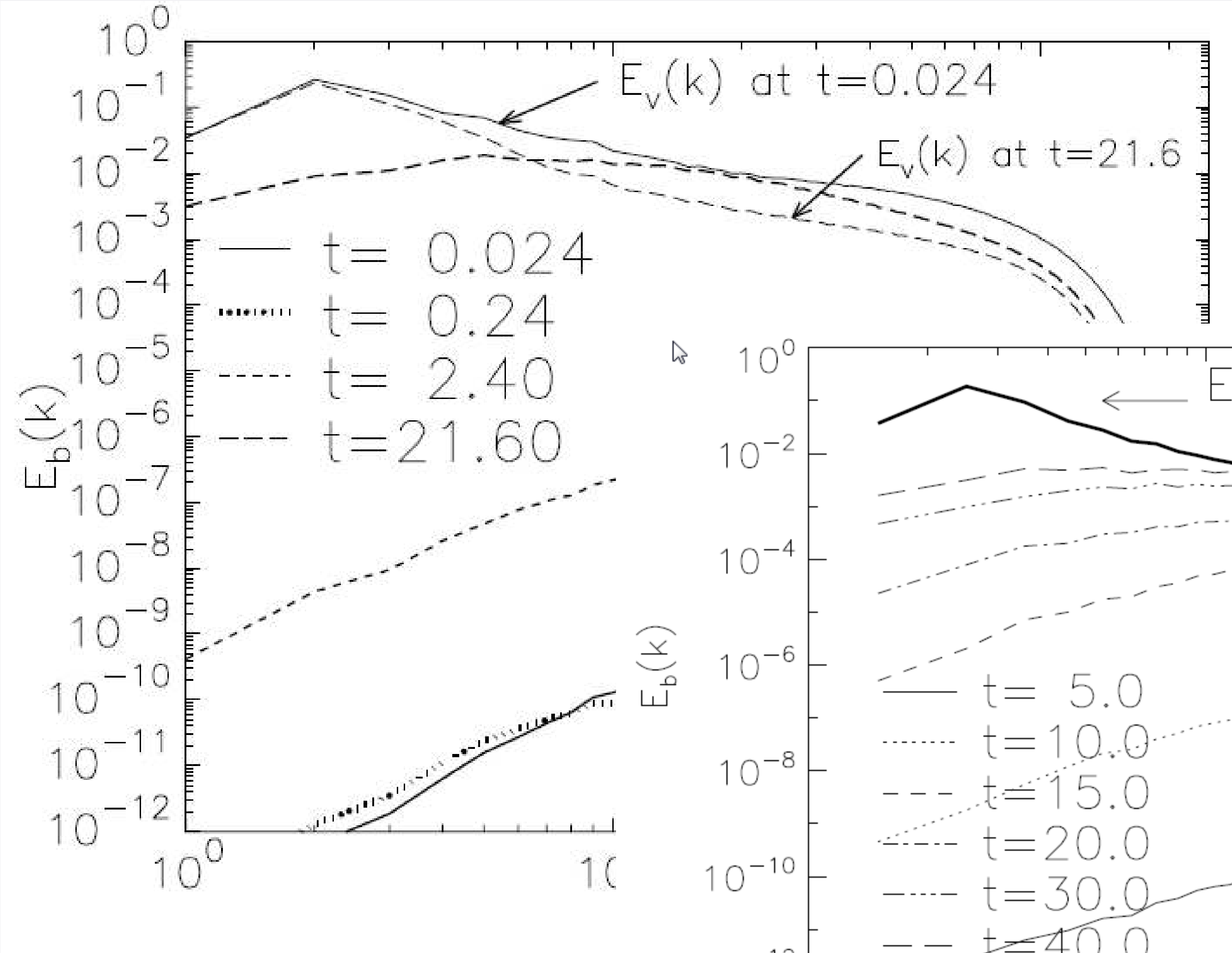
Time evolution of B^2 and v^2 : very similar to uniform seed field cases

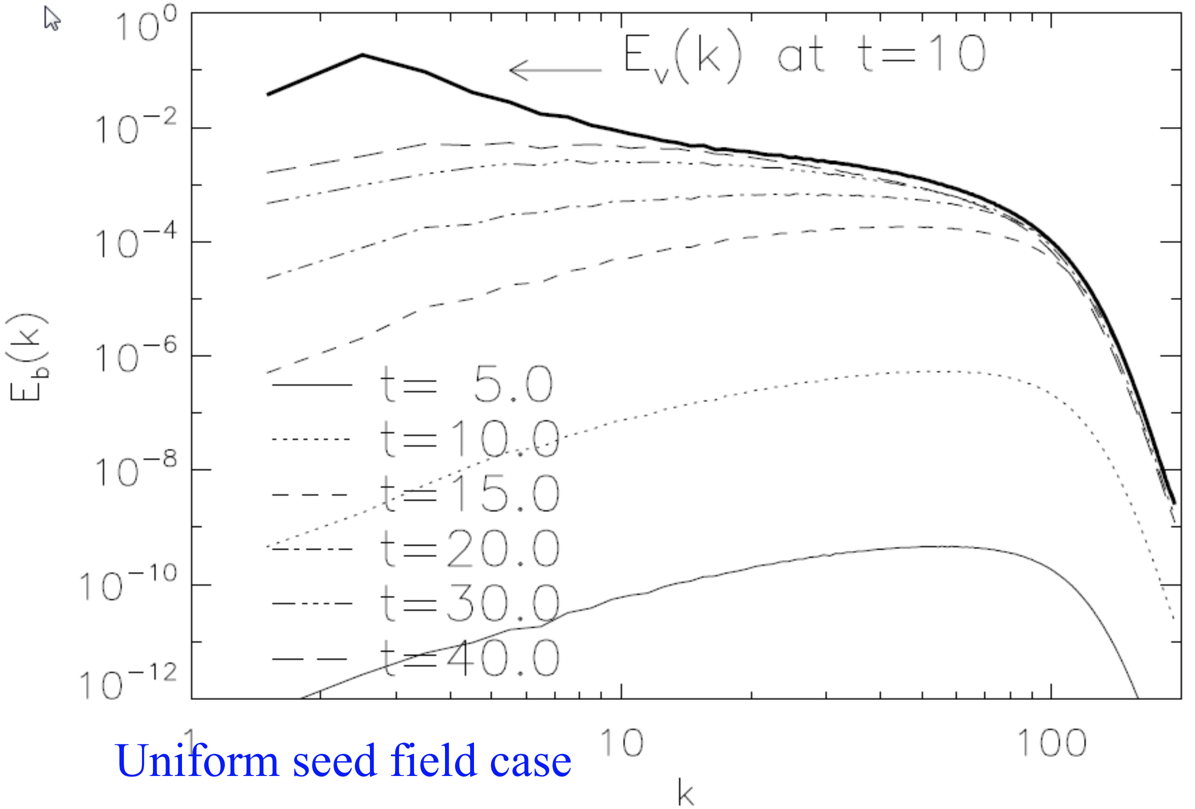


Saturation time-scale ~ 15 (L/v)

Cho & Yoo (2012)

Time evolution of $E_b(k)$: very similar to uniform seed field cases

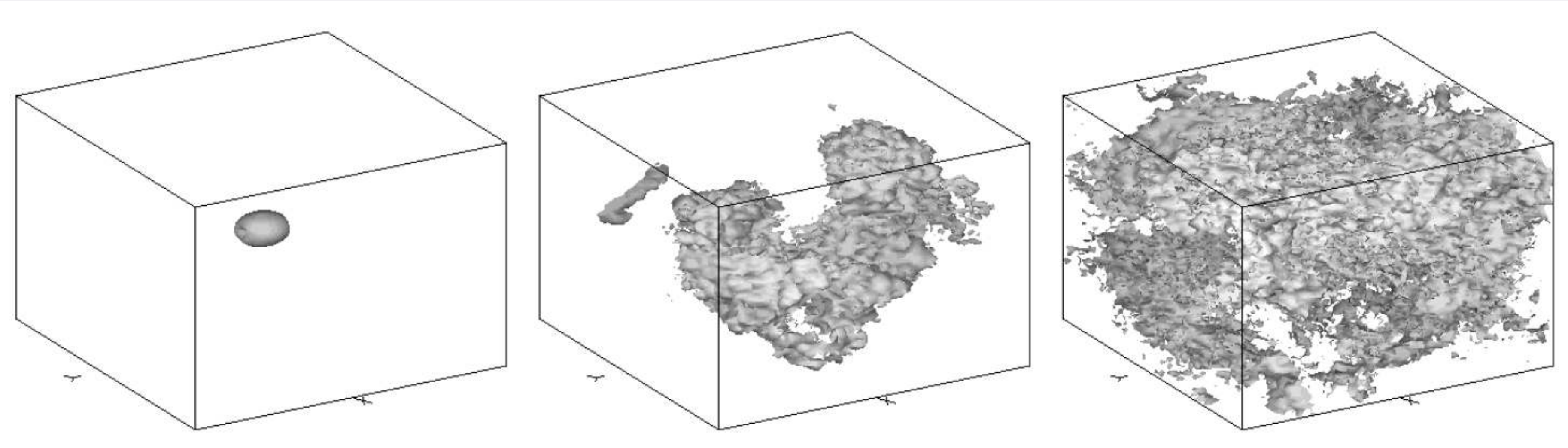




Uniform seed field case

Why are the results so similar?

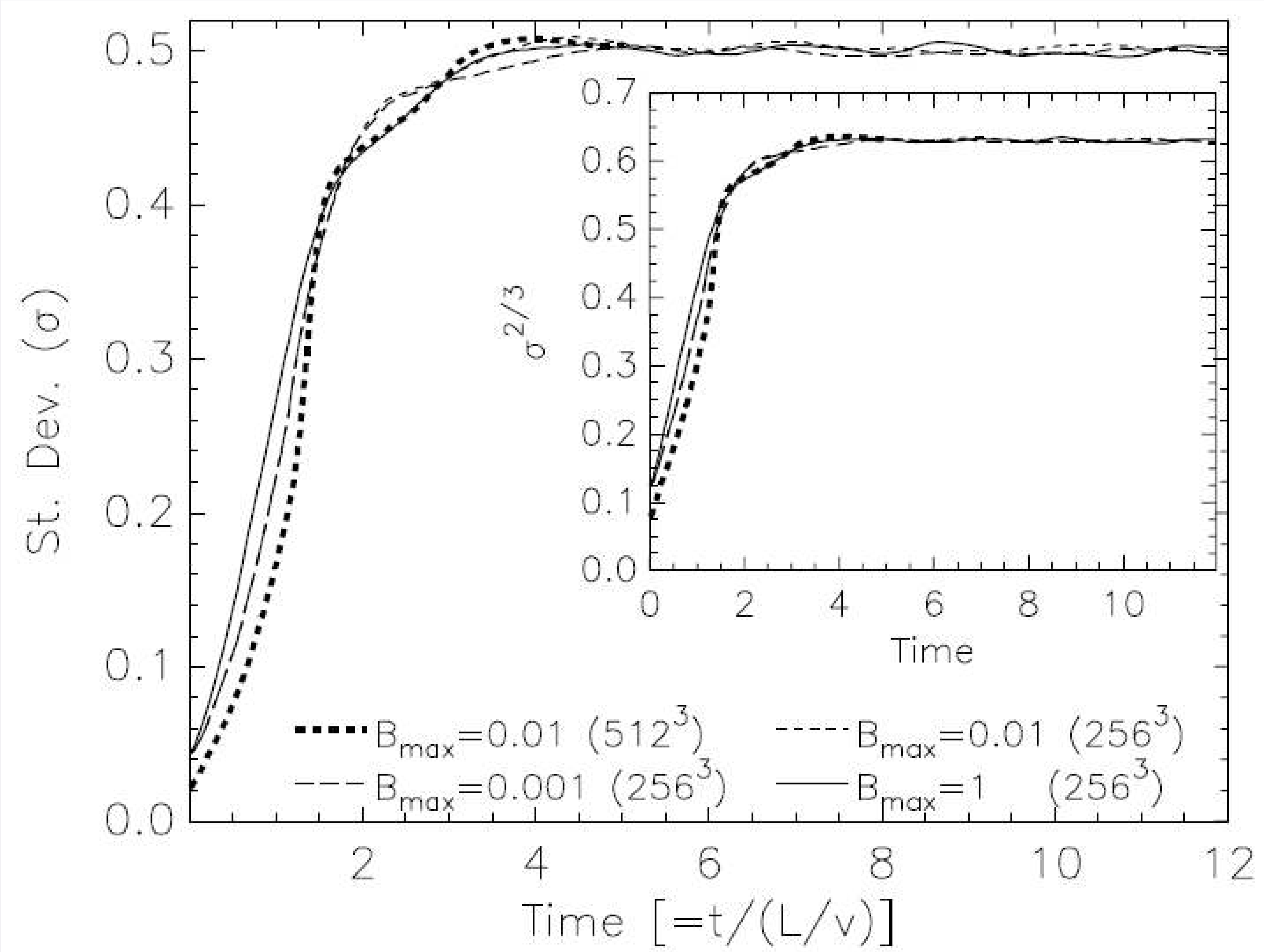
➔ Answer: fast magnetic diffusion



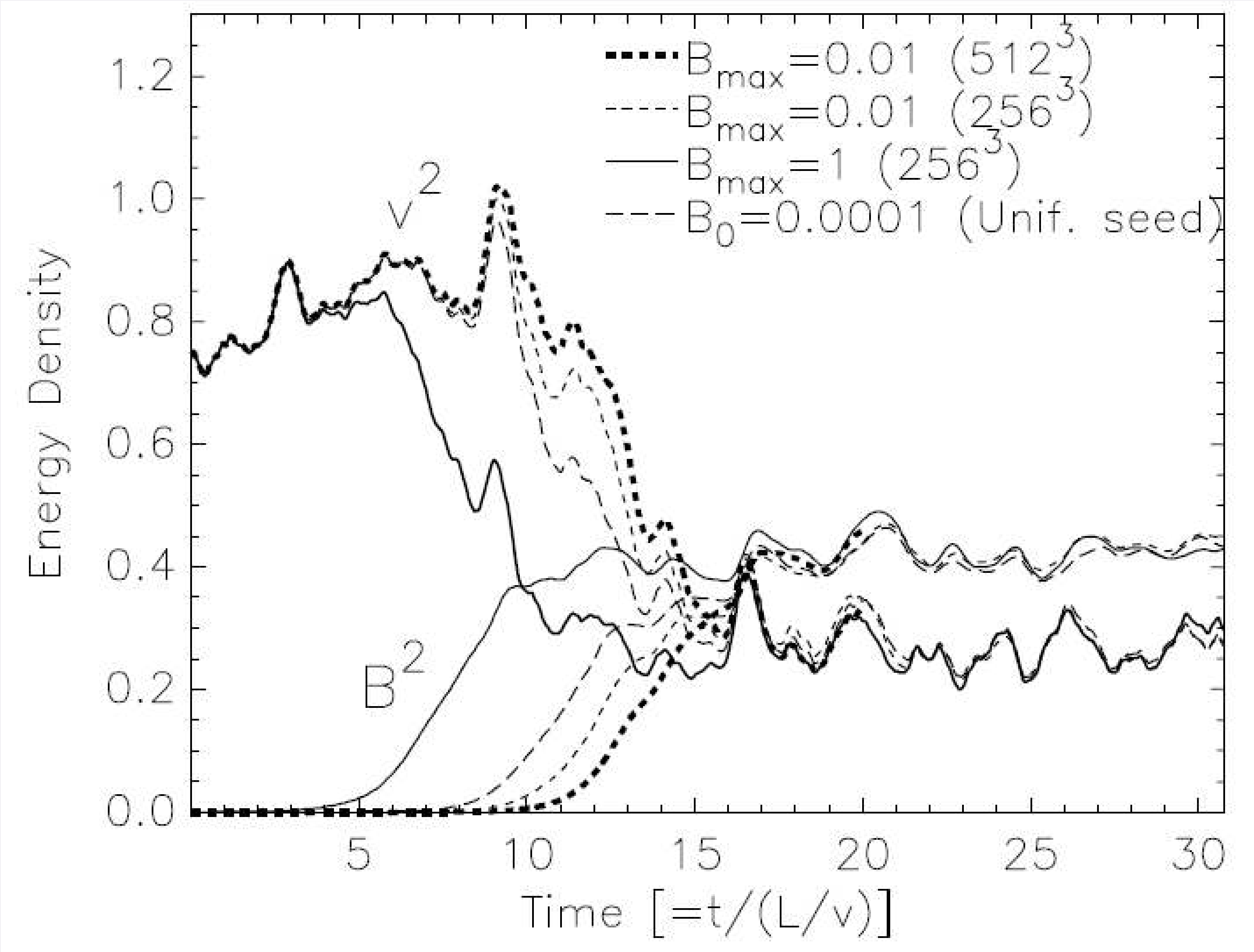
t=0 t=1.2(L/v) t=2.4(L/v)

After magnetic field fills the whole system, the subsequent evolution should be very similar to uniform seed field cases

St. dev. of B field distribution confirms this

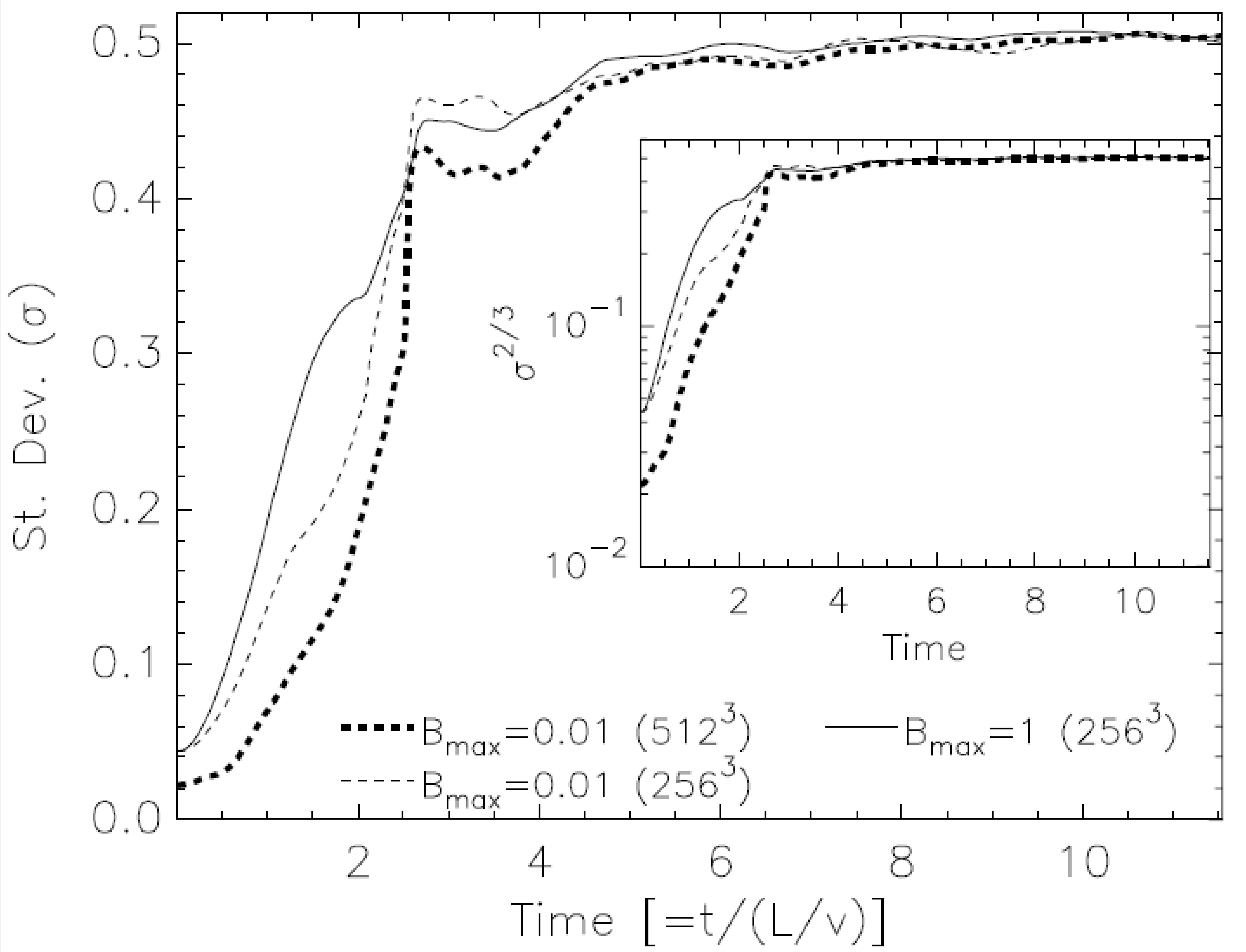


Cf) Growth of a localized magnetic field in turbulence with a high magnetic Prandtl number (i.e. ν >> η)

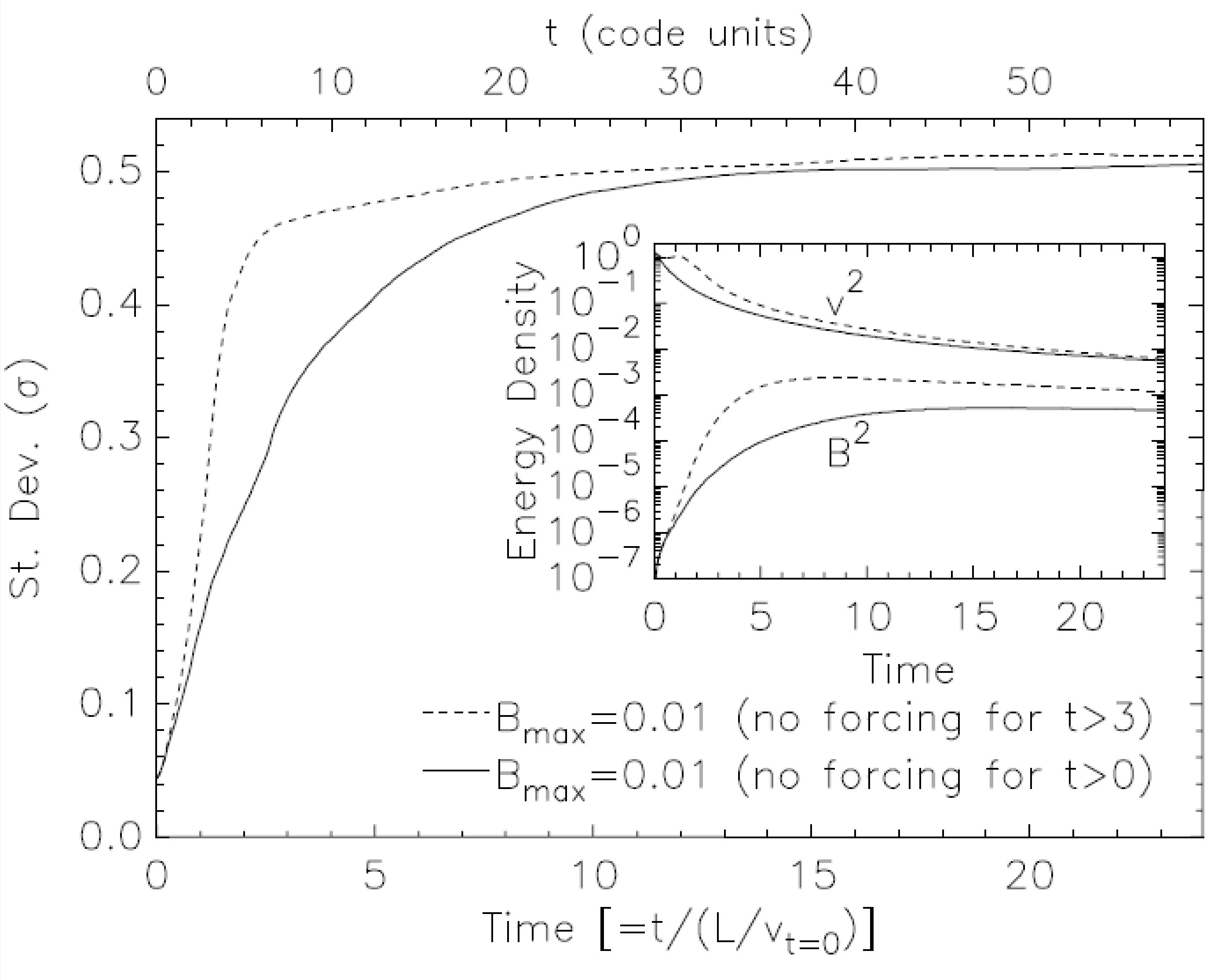


Cho & Yoo (2012)

Magnetic field fills the whole system fast



Cf) Magnetic field can fill the whole system even in a decaying turbulence



Cho & Yoo (2012)