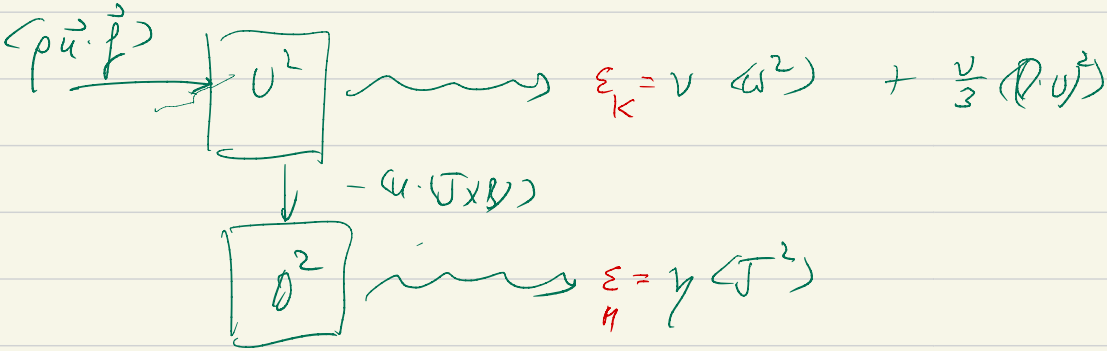
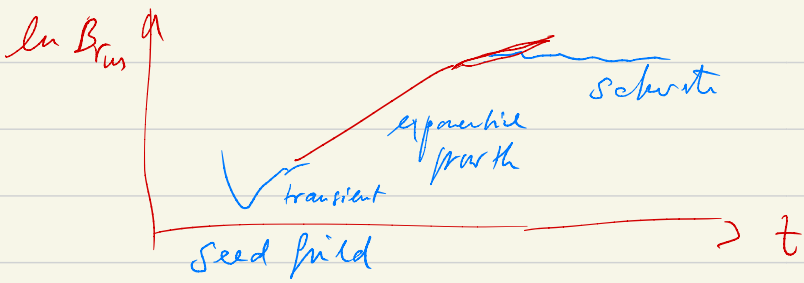
(Axel's plan)

Astrophysical turbulent dynamo.



Magnetic field amplification



statistically steady state ?

*) Collapse $u_{rms} \uparrow$

*) decaying turbulence $u_{rms} \downarrow$

Relation to our interests

turbulent mixing

dissipation

Observational constraints

particle acceleration

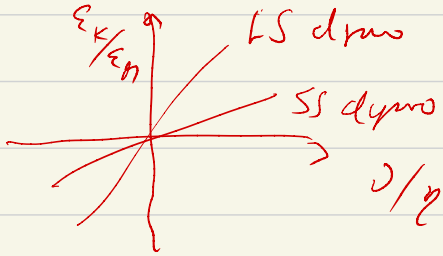
- The role of turbulence in the formation history of galaxy disks and bulges
- The impact of turbulence in rapidly star-forming galaxies and its connection to the driving of galaxy outflows
- The physics of turbulent mixing in the interstellar and intergalactic media
- The role of hydrodynamic and plasma instabilities in galaxies and galaxy clusters
- The physics of turbulent dissipation in multi-phase astrophysical media from hot and diffuse to cold and dense
- Observational constraints of turbulence in the intracluster and circumgalactic media
- The role of turbulence in particle acceleration and magnetic field amplification

$Ma \gg 1$

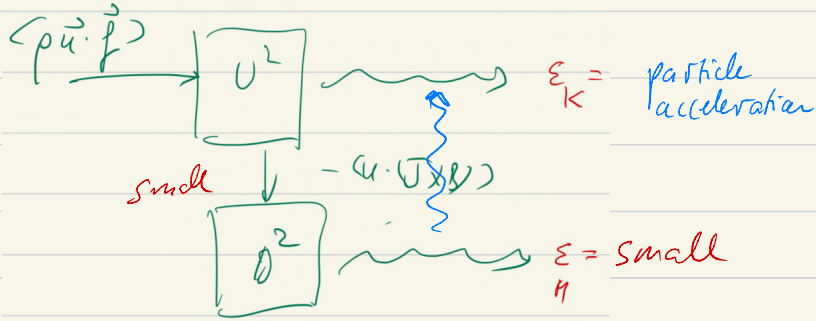
$\nu/\eta \gg 1$

AD

$\eta \to 0$ dynamo efficient



??



dynamo inefficient

Brandenburg, A., & Rempel, M.: 2019, ``Reversed dynamo at small scales and large magnetic Prandtl number,'' *Astrophys. J.*, in press (arXiv:1903.11869, ADS, HTML, PDF)

Suggestions / questions

Magnetic energy dissipated viscously (in MHD)

? particle acceleration in kinetic theory?

Field amplification

exponential (usually) $\frac{\partial \vec{B}}{\partial t} = \nabla \times (\vec{v} \times \vec{B}) + \eta \nabla^2 \vec{B}$

complications when $v_{rms} \neq$ const

empirically $\tau^{-1} \lambda = \frac{d \ln B_{rms}}{dt} \frac{1}{v_{rms} k_f}$

= useful measure

Dynamos in decaying turbulence

decay slower than normally

$E \sim t^{-10/7}$ $\xi \sim t^{2/7}$

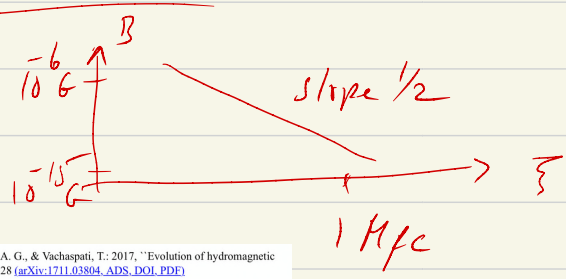
GW

in helical turbulence

$E \sim t^{-2/3}$ $\xi \sim t^{2/3}$

Observational constraints. (i) intracluster

lower limit



Brandenburg, A., Kahniashvili, T., Mandal, S., Roper Pol, A., Tevzadze, A. G., & Vachaspati, T.: 2017, ``Evolution of hydromagnetic turbulence from the electroweak phase transition," *Phys. Rev. D* **96**, 123528 (arXiv:1711.03804, ADS, DOI, PDF)

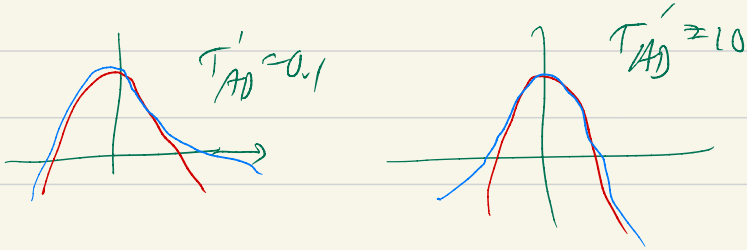
(ii) galactic foreground

$$\tilde{E} + i\tilde{B} = (\hat{k}_x - i\hat{k}_y)^2 (\tilde{Q} + i\tilde{U})$$

$$E^2/B^2 \simeq 2 \quad !? \quad \text{Planck}$$

signature of turbulence!

skewness of E



Brandenburg, A.: 2019, ``Ambipolar diffusion in large Prandtl number turbulence," *Mon. Not. Roy. Astron. Soc.*, in press (arXiv:1903.08976,

Brandenburg, A., Bracco, A., Kahniashvili, T., Mandal, S., Roper Pol, A., Petrie, G. J. D., & Singh, N. K.: 2019, `` E and B polarizations from inhomogeneous and solar surface turbulence," *Astrophys. J.* **870**, 87 (arXiv:1807.11457, ADS, DOI, PDF)

Turbulent mixing

$$\frac{\partial}{\partial t}\langle c^2\rangle = \ldots - 2\langle \rho\kappa (\nabla c)^2\rangle$$

vs. $$\frac{\partial}{\partial t}\langle c\rangle = \qquad + \kappa_t \nabla^2 \langle c\rangle .$$

Galactic dynamo

growth rate of M

quadrupole dynamo

Evan

	M_a	Pr_M	$B^2/2\mu_0$	Particle accel
ISM	$\gg 1$	$\gg 1$	1	
CGM circumgalactic medium	range	$\gg 1$		
ICM	< 1	0.1 ... 100 ?		

why!

do hydro simulation how wrong is that.

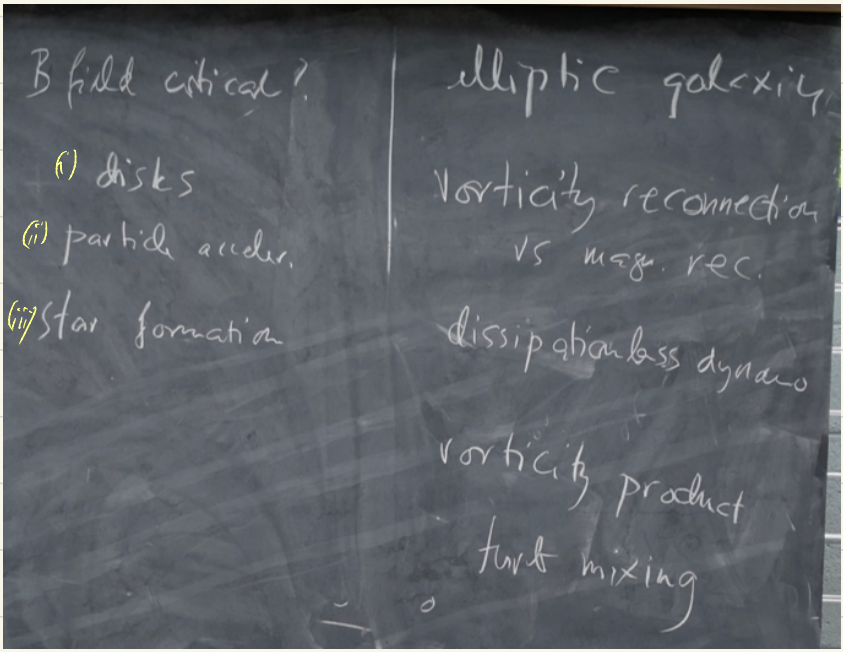
Most of energy in thermal electrons, not fast particles

But a lot is in protons.

But get different answer if diffusion coefficient is changed?

Topics emerging during discussion

where is:



ICM 1 μG but small compared with pressure.