Planck-scale axion and SU(2) YM thermodynamics
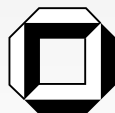
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plan

▶ photon propagation $\leftrightarrow$ dark energy $\leftrightarrow$ SU(2) YM ?

▶ de- and preconfining SU(2) YM TD

▶ Planck-scale axion and dark energy
  [Frieman et al., PRL 1995]

▶ physics at the phase boundary

▶ outlook:
  CMB power spectra at large angles, BBN, ew SB

photons: SU(2) YM ??

►   SU(2) YM $\xrightarrow{\text{deconf.}}$ U(1)   plus

    – nontrivial ground state
      (topolog. fluctuations, axion mass!)
      [RH, IJMPA 2005; MPLA 2006]

    – massless γ; massive and weakly interacting,
      charged vector excitations $V^{\pm}$ which
      decouple at phase boundary
      [Herbst, RH, Rohrer, AcPP 2005;
      Schwarz, RH, Giacosa, IJMPA 2007; JHEP 2007]

    $\Rightarrow$ postulate: $\text{SU(2)}_{\text{CMB}} \overset{\text{today}}{=} \text{U(1)}_Y$
      [RH, PoS (JHW2005)]

phase diagram: SU(2) YM TD

confining

preconfining

deconfining

ground state:

Cooper–pair condensate of single center–vortex loops, pressure precisely zero

excitations:

massless (single) and massive (self–intersecting) center–vortex loops (spin–1/2 fermions)

ground state:

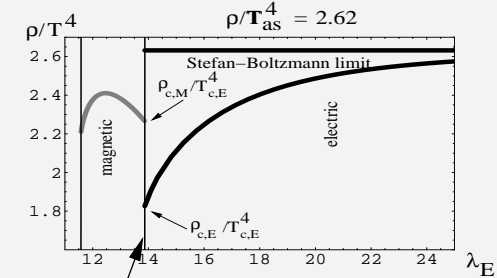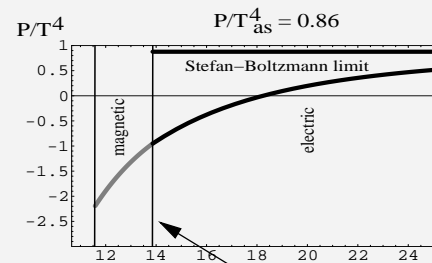condensate of magnetic monopoles, collapsing center–vortex loops, negative pressure

excitations:

massive dual gauge modes

ground state: interacting calorons and anticalorons, negative pressure

excitations: massless and massive gauge modes

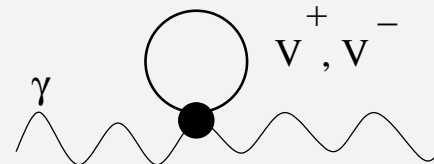power–like approach to Stefan Boltzmann limit

P/T^4 $P/T^4_{as} = 0.86$

Stefan–Boltzmann limit

magnetic   electric

1
0.5
0
-0.5
-1
-1.5
-2
-2.5

12 14 16 18 20 22 24

ρ/T^4 $\rho/T^4_{as} = 2.62$

Stefan–Boltzmann limit

$\rho_{c,M}/T^4_{c,E}$

magnetic   electric

$\rho_{c,E}/T^4_{c,E}$

2.6
2.4
2.2
2
1.8

12 14 16 18 20 22 24 λ_E

decoupling of V^+, V^-, no (anti) screening

$T_c = 2.73$ K $\longrightarrow \Lambda \sim 10^{-4}$ eV

T_c

Hagedorn   2nd order like

γ V^+, V^- (anti) screening

T

axion + CDM cosmology: ($0 \leq z \leq 1089$)

▶ axion potential (canon. kin. term):

$$V(\phi) = (\lambda \Lambda)^4 \left[1 - \cos\left(\frac{\phi}{F}\right) \right]$$

▶ typical parameter values:

$$\frac{\phi_{\text{in}}}{M_P} = \frac{3\pi}{4}; \; \lambda = 22.15; \; t_0 = 13.65\,\text{Gy};$$
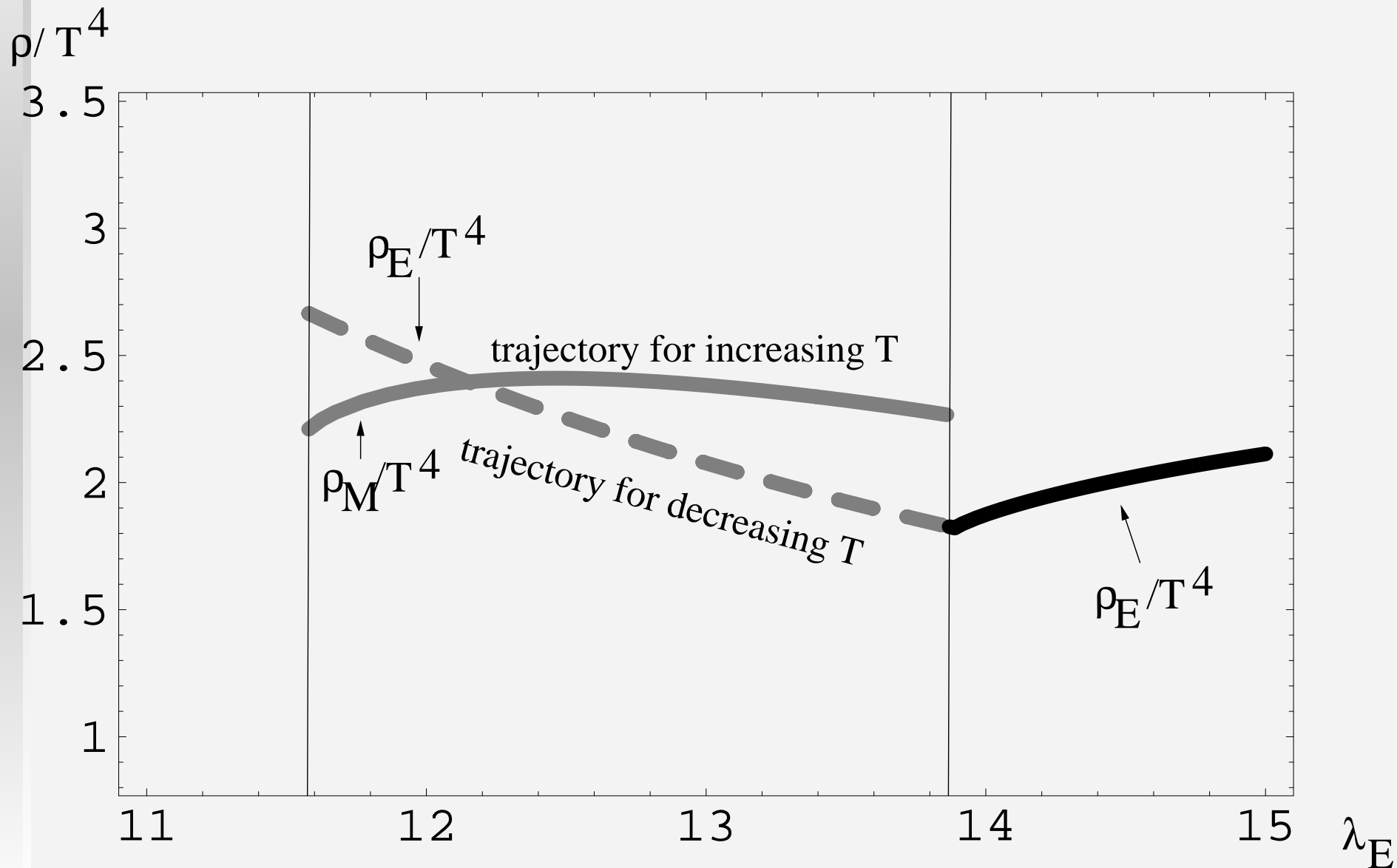
$$w_\phi(t_0) = -0.97; \; z_{\text{acc}} = 0.76; \; \frac{F}{M_P} = 0.5$$

[Frieman et al., PRL 1995; Giacosa, RH, EPJC 2007]

▶ axion decay width:

$$\Gamma_{\phi \to 2\gamma} \sim \left(\frac{m_\phi}{F}\right)^2 m_\phi \; \sim 10^{-155}\text{eV} \lll H_0 \sim 10^{-33}\text{eV}$$

physics at the phase boundary

► maximal duration of supercooled situation: ($m_\gamma = 0$ and no screening):

$$\Delta t_{m_\gamma=0} = (2.2 \pm 0.15)\,\mathrm{Gy}$$

► Does $\Delta t_{m_\gamma=0}$ change if axion responsible for both DE and DM today? (galaxies $\leftrightarrow$ axion lumps)
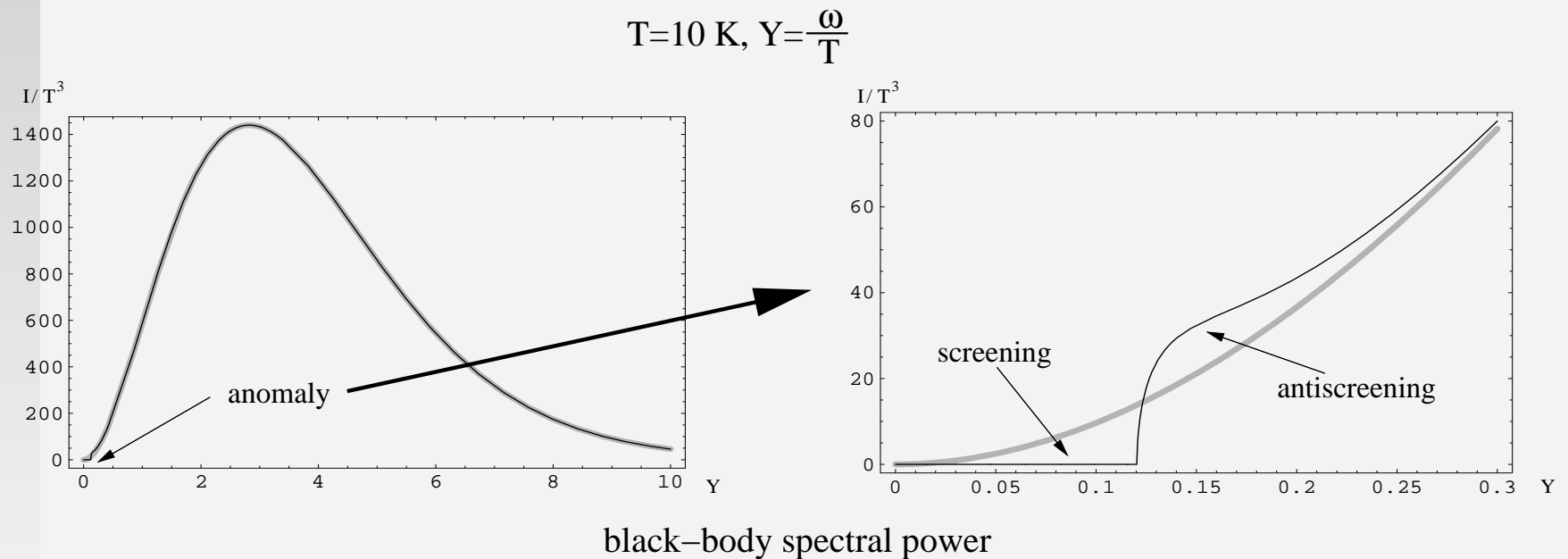[Wetterich, PLB 2001]

$$\Delta t_{m_\gamma=0} = (2.1 \pm 0.15)\,\mathrm{Gy}$$

but:
− $t_0 \sim 20\,\mathrm{Gy}$; $z_{\mathrm{acc}} \sim 3$ (structure formation?!)
− DM, DE not separately conserved
− DM part ($p = 0$) nominal strength only recently

outlook: SU(2)$_{\text{CMB}}$

► visible black-body spectral anomaly for
$3\,\text{K} \leq T \leq 20\,\text{K}$

$T = 10\text{ K},\ Y = \dfrac{\omega}{T}$

black–body spectral power

[Schwarz, RH, Giacosa, JHEP 2007]

outlook: SU(2)$_{\text{CMB}}$

▶ dynamic contribution to CMB dipole?
(discrepancy: inferred, observed Local-Group vel.)

[Erdogdu et al., MNRAS 2006; Brent Tully astro-ph/0611357; Szopa, RH, hep-ph/0703119]

▶ statistical isotropy for large-angle correlations in CMB?

[Copi et al., PRD 2007]

▶ implications for freeze-out physics in BBN
(proper mechanism for ew SB?)

[Giacosa, RH, EPJC 2007; Schwarz, RH, Giacosa, JHEP 2007]

Thank you.