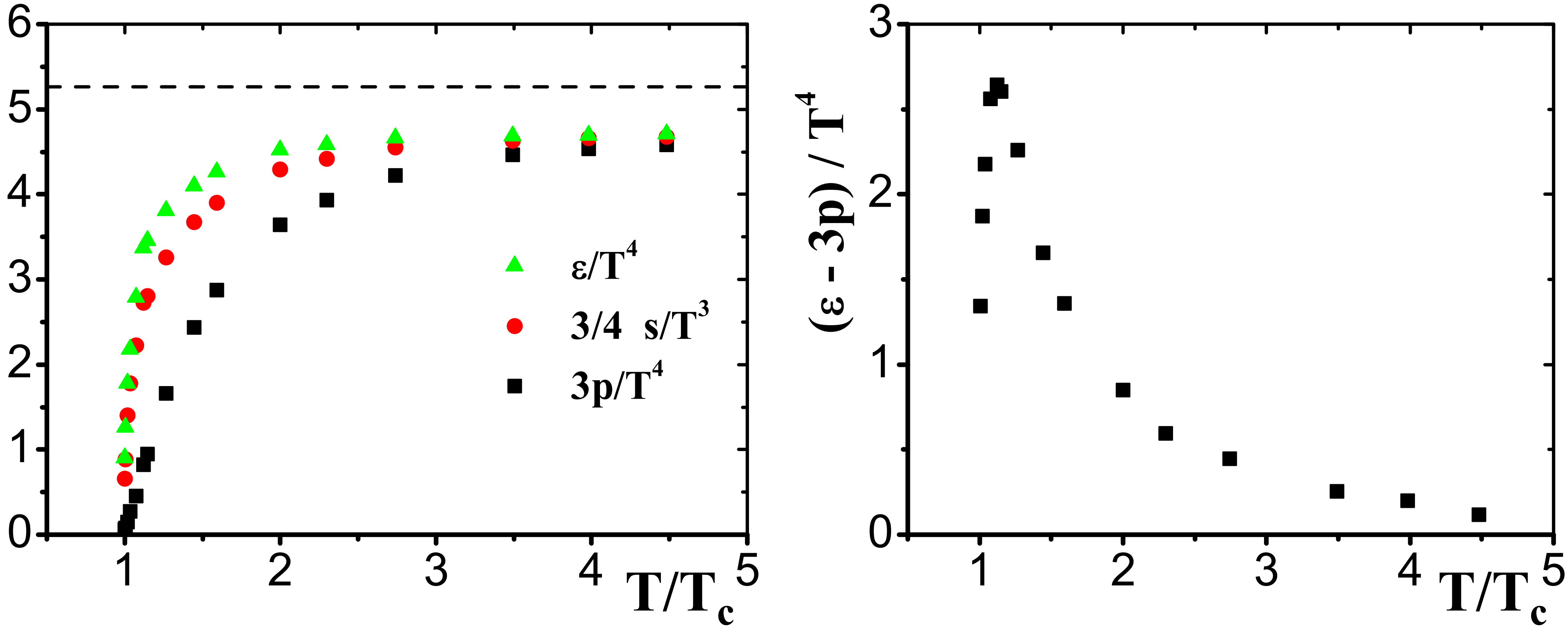
Quasiparticle Approach to Gluon Plasma Equation of State

V.V. Begun, M.I. Gorenstein, and O.A. Mogilevsky

Bogolyubov Institute for Theoretical Physics, Kiev, Ukraine



F. Karsch, et al, Phys. Lett. B 478 (2000) 447.

$$N_\tau = 4, 6, 8; \qquad N_\sigma \to \infty$$

QUASIPARTICLE MODELS

$$E^2(k) \;=\; k^2 + m^2(T)$$

$$P(T) = \frac{d}{6\pi^2}\int_0^\infty dk f_B(E)\frac{k^4}{E} - B(T)$$

where $d = 2(N_c^2 - 1)$ is the gluon degeneracy factor and

$$f_B(E) = \frac{1}{\exp(E/T) - 1}$$

The energy density ε and the entropy density s are equal to:

$$\begin{aligned}\varepsilon(T) &= \frac{d}{2\pi^2}\int_0^\infty dk k^2 f_B(E) E + B(T)\\ s(T) &= \frac{d}{2\pi^2 T}\int_0^\infty dk k^2 f_B(E)\frac{(4/3)k^2 + m^2}{E}\end{aligned}$$

Selfconsistent requirement

$$\varepsilon = T\frac{dP}{dT} - P$$

$$B(T) \ = B\ (T_0) + \int_{T_0}^{T} dT' \frac{dm(T')}{dT'} \frac{\partial P_{id}(m, T')}{\partial m}$$

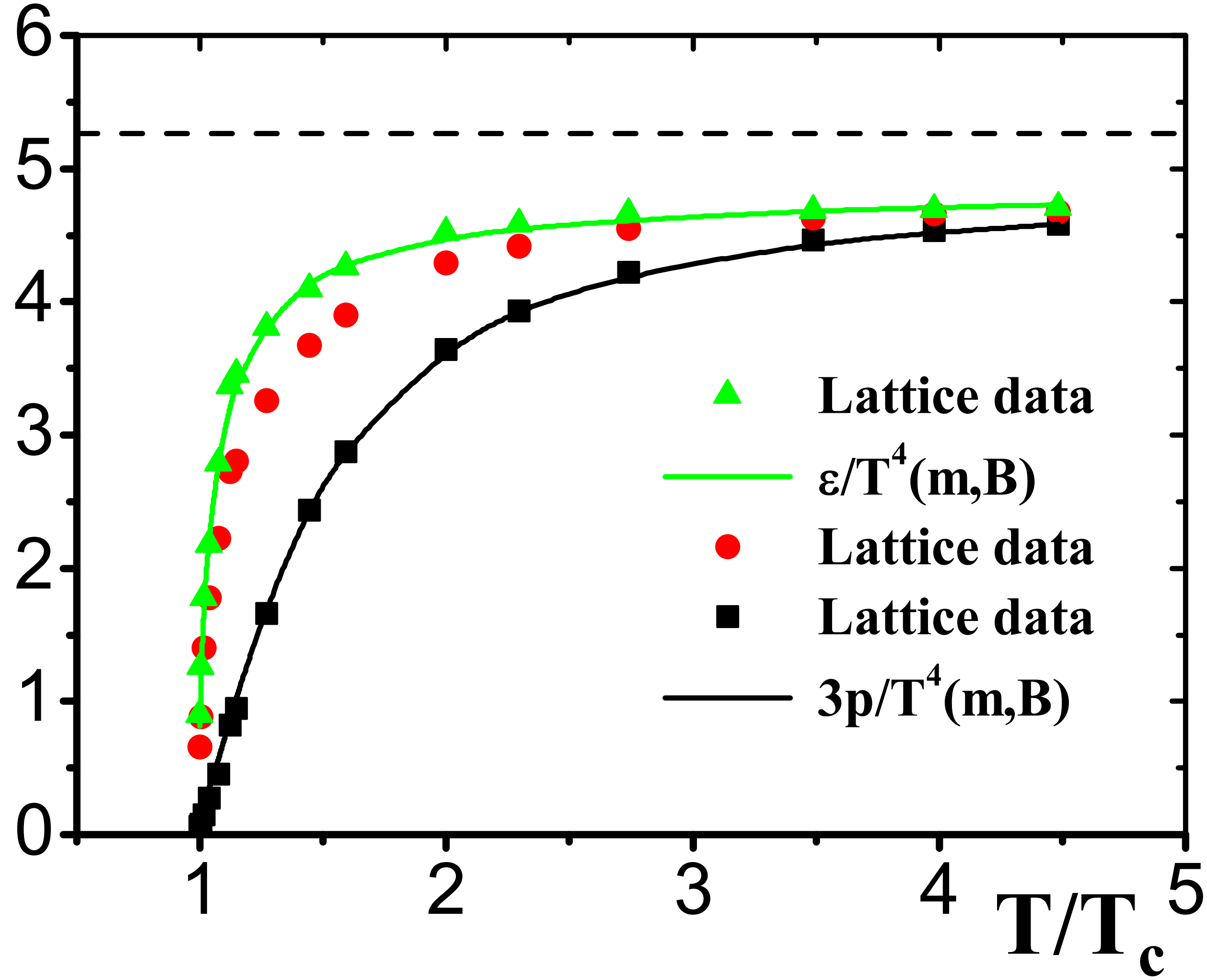
M.I.G., Shin Nan Yang. Phys. Rev. D52, 5206 (1995)

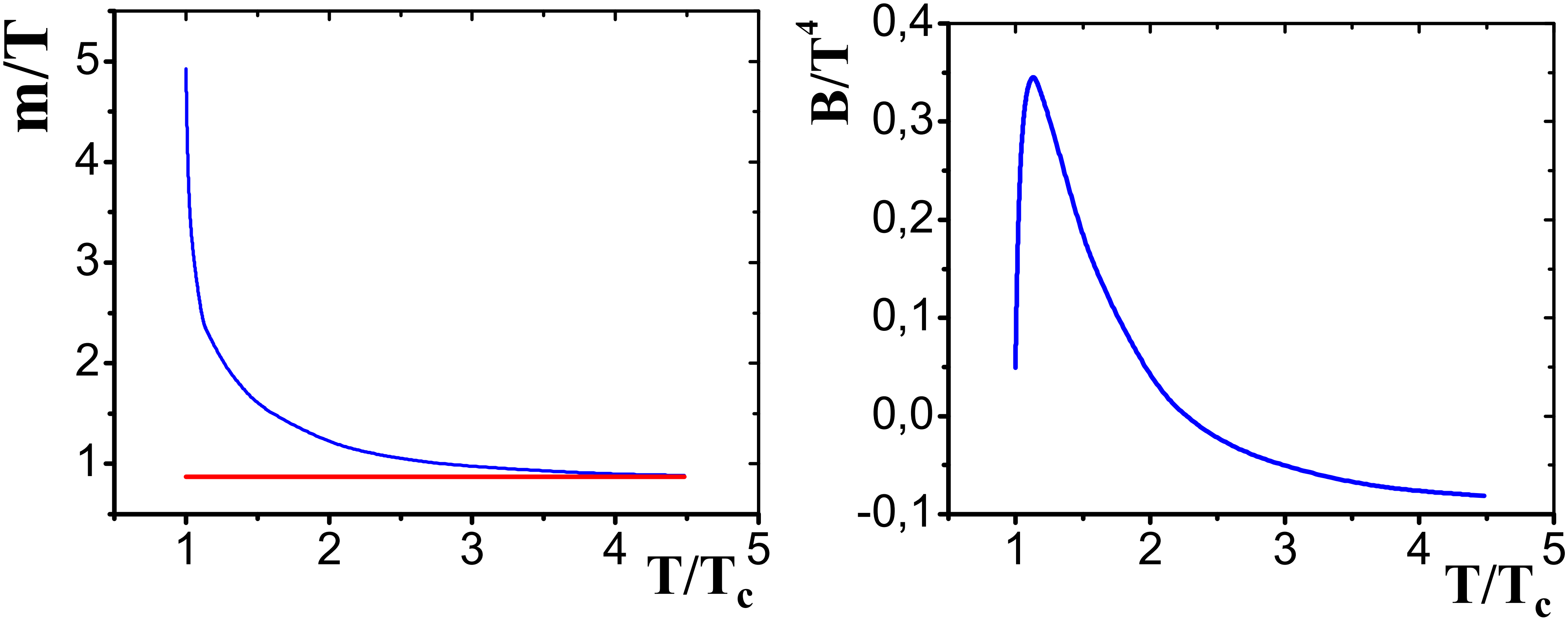
The general solution of the thermodynamical identity has the form:

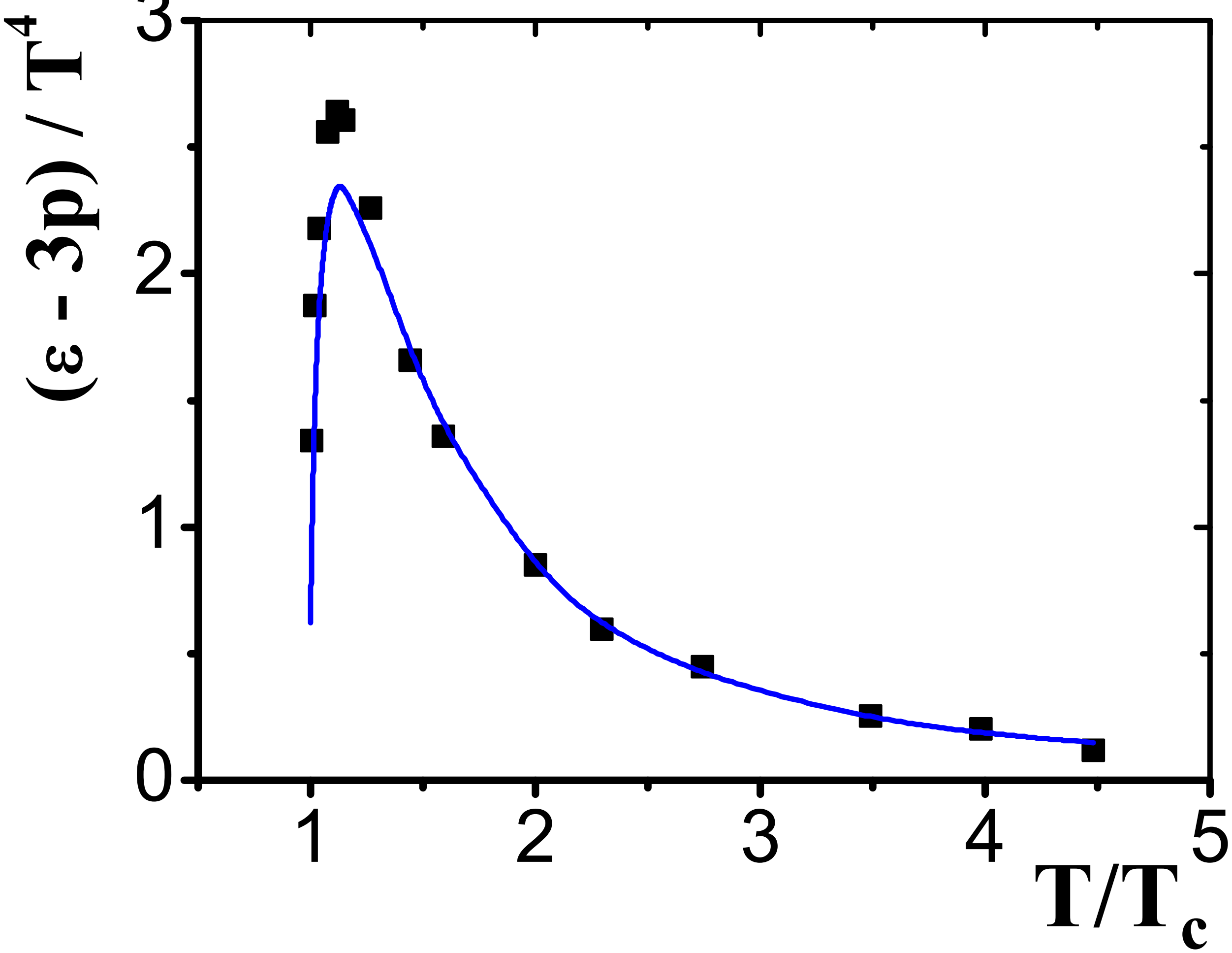
$$P(T) = T\left[\int \varepsilon(T)\frac{dT}{T^2} + C\right]$$

M.I.G., O.A. Mogilevsky, Z. fur Phys. **38**, 161 (1988)

Here C is an integration constant. The $P(T)$ contains more information on the system than $\varepsilon(T)$.


6
5
4
3
2
1
0
1
2
3
4
5
T/Tc
Lattice data
ε/T4(m,B)
Lattice data
Lattice data
3p/T4(m,B)


m/T
5
4
3
2
1
1
2
3
4
5
T/T_c
B/T^4
0,4
0,3
0,2
0,1
0,0
-0,1
1
2
3
4
5
T/T_c



$$\Delta \equiv \varepsilon - 3P$$

QUASIPARTICLE MODEL WITH $m = aT$

$$\begin{aligned} P &= P_{id} - B(T) - A \cdot T \\ \varepsilon &= \varepsilon_{id} + B(T) \end{aligned}$$

where

$$\begin{aligned} P_{id} &= \frac{dT^4}{2\pi^2} \sum_{n=1}^{\infty} \frac{a^2}{n^2} K_2(na) \\ \varepsilon_{id} &= \frac{dT^4}{2\pi^2} \sum_{n=1}^{\infty} \frac{a^3}{n} [K_1(na) + 3K_2(na)/na] \end{aligned}$$

For $m = aT$ the function $B(T)$ is exactly calculated

$$B(T) = B_0 - \frac{1}{4}\Delta_{id} \ , \qquad \Delta_{id} \equiv \varepsilon_{id} - 3P_{id}$$

Then

$$\begin{aligned} P &= \frac{1}{3}\sigma T^4 \ - \ B_0 \ - \ A \cdot T \\ \varepsilon &= \sigma T^4 \ + \ B_0 \\ \Delta &= \varepsilon - 3P \ = \ 4B_0 \ + \ 3A \cdot T \end{aligned}$$

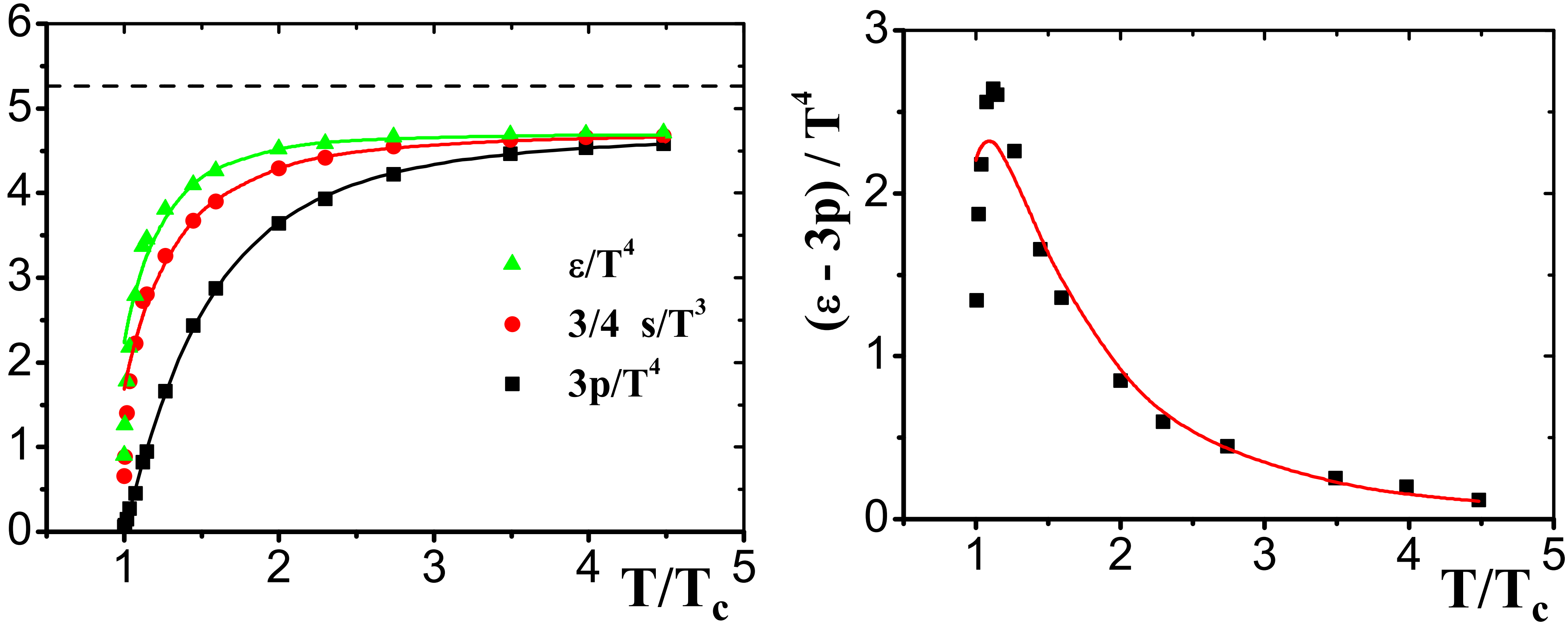
where

$$\sigma = \frac{3d}{2\pi^2} \sum_{n=1}^{\infty} \left[\frac{a^2 K_2(na)}{n^2} + \frac{1}{4} \frac{a^3 K_1(na)}{n} \right]$$

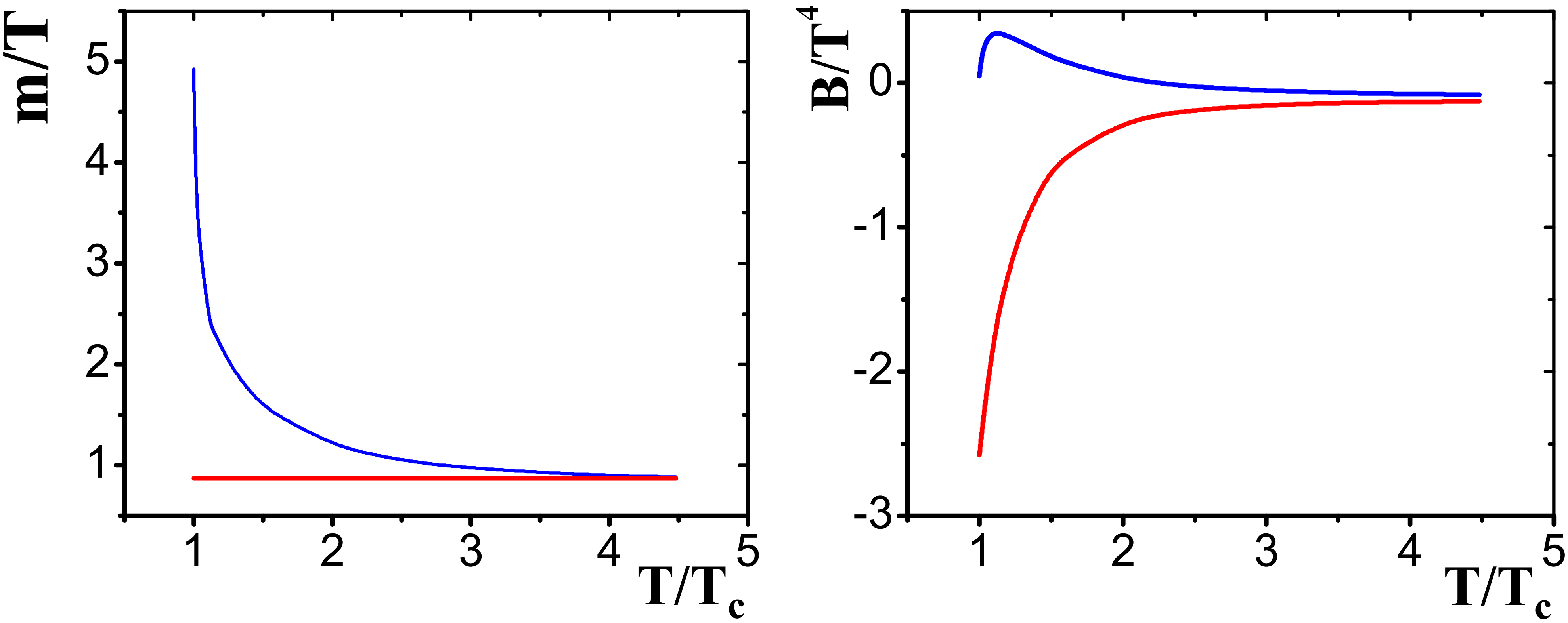
The system behaves like ideal gas of massless particles with $\sigma < \sigma_{\mathrm{SB}} = 2(N_c^2 - 1)\frac{\pi^2}{30}$.

Comparison with result of lattice calculations gives

$$\begin{aligned} B_0 &= -(2.49 \pm 0.08) T_c^4 \\ A &= (4.07 \pm 0.09) T_c^3 \\ a &= 0.87 \end{aligned}$$



ε/T⁴
3/4 s/T³
3p/T⁴
T/Tc
(ε - 3p) / T⁴
T/Tc



m/T
5
4
3
2
1
1
2
3
4
5
T/T_c
B/T^4
0
-1
-2
-3
1
2
3
4
5
T/T_c

Conclusions:

1) At high T the A and B_0 constants become unimportant.
The linear relation $m = aT$ seems to be unavoidable and leads to quasi-SB gas with $\sigma < \sigma_{SB}$.

2) At T close to T_c different quasi-particle descriptions are possible.
At $m = aT$ the bag constant B_0 is negative.

3) QCD lattice data for other observables should be analyzed.