Dyson-Schwinger 方程式を用いた熱準粒子構造の解析

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Hard-Thermal-Loop Resummed
Dyson-Schwinger Equations(Real Time Formalism)

$$-i\Sigma_R(P) = -\frac{e^2}{2}\int \frac{d^4K}{(2\pi)^4}\times\Big[\Gamma^{\mu}_{RAA} S_R(K)\Gamma^{\nu}_{RAA} G_{C,\mu\nu}(P-K)$$
$$+\Gamma^{\mu}_{RAA} S_C(K)\;\Gamma^{\nu}_{AAR} G_{R,\mu\nu}(P-K)\;\Big]$$

$$G_R^{\mu\nu}(K) = \frac{1}{\Pi_T^R - K^2 - i\varepsilon k_0}A^{\mu\nu} + \frac{1}{\Pi_L^R - K^2 - i\varepsilon k_0}B^{\mu\nu} - \frac{\xi}{K^2 + i\varepsilon k_0}D^{\mu\nu}$$

$$A^{\mu\nu} = g^{\mu\nu} - B^{\mu\nu} - D^{\mu\nu}, B^{\mu\nu} = -\frac{\tilde{K}^{\mu}\tilde{K}^{\nu}}{K^2}, D^{\mu\nu} = \frac{K^{\mu}K^{\nu}}{K^2}, \tilde{K} = (k, -k_0\vec{k})$$

$$\Gamma^{\mu} = \gamma^{\mu}$$ ← Ladder 近似

$$\Sigma_R(P) = (1 - A(P)\;)\,p_i\gamma^i - B(P)\gamma_0 + C(P)$$

Themal Quasi-Particleの振る舞い

Symmetric Phase（$C=0$）、Landau gauge

$$S_R = \frac{1}{2}\left[\frac{1}{D_+}\left(\gamma^0+\frac{p_i\gamma^i}{p}\right)+\frac{1}{D_-}\left(\gamma^0-\frac{p_i\gamma^i}{p}\right)\right]$$

Spectral Function

$$\rho_\pm(p_0,p) = -\frac{1}{\pi}\mathrm{Im}\frac{1}{D_\pm(p_0,p)} = -\frac{1}{\pi}\mathrm{Im}\frac{1}{p_0+B(p_0,p)\mp pA(p_0,p)}$$

Dispersion Relation

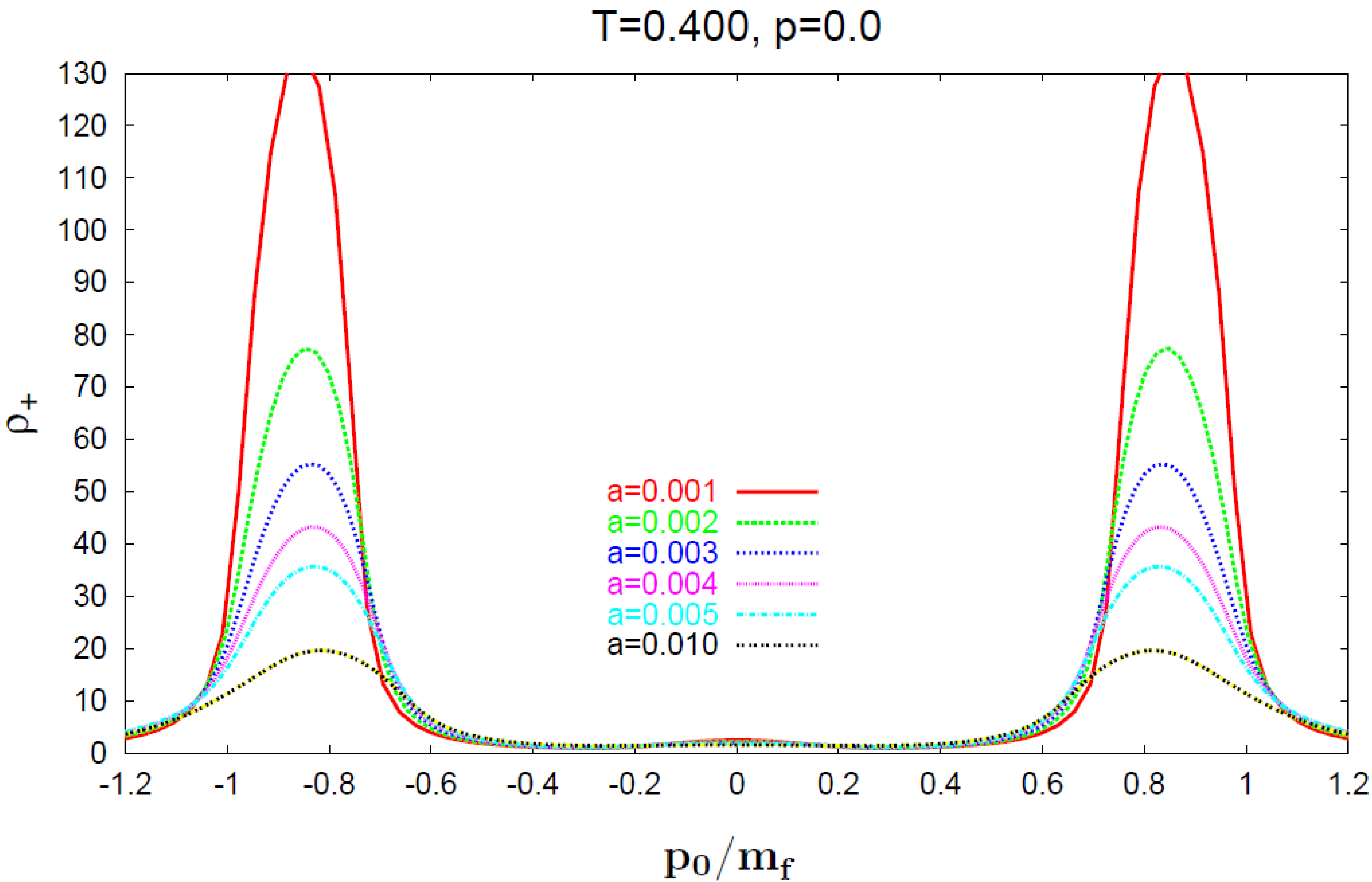
$$\mathrm{Re}[D_+(p_0=\omega,p)]=0$$

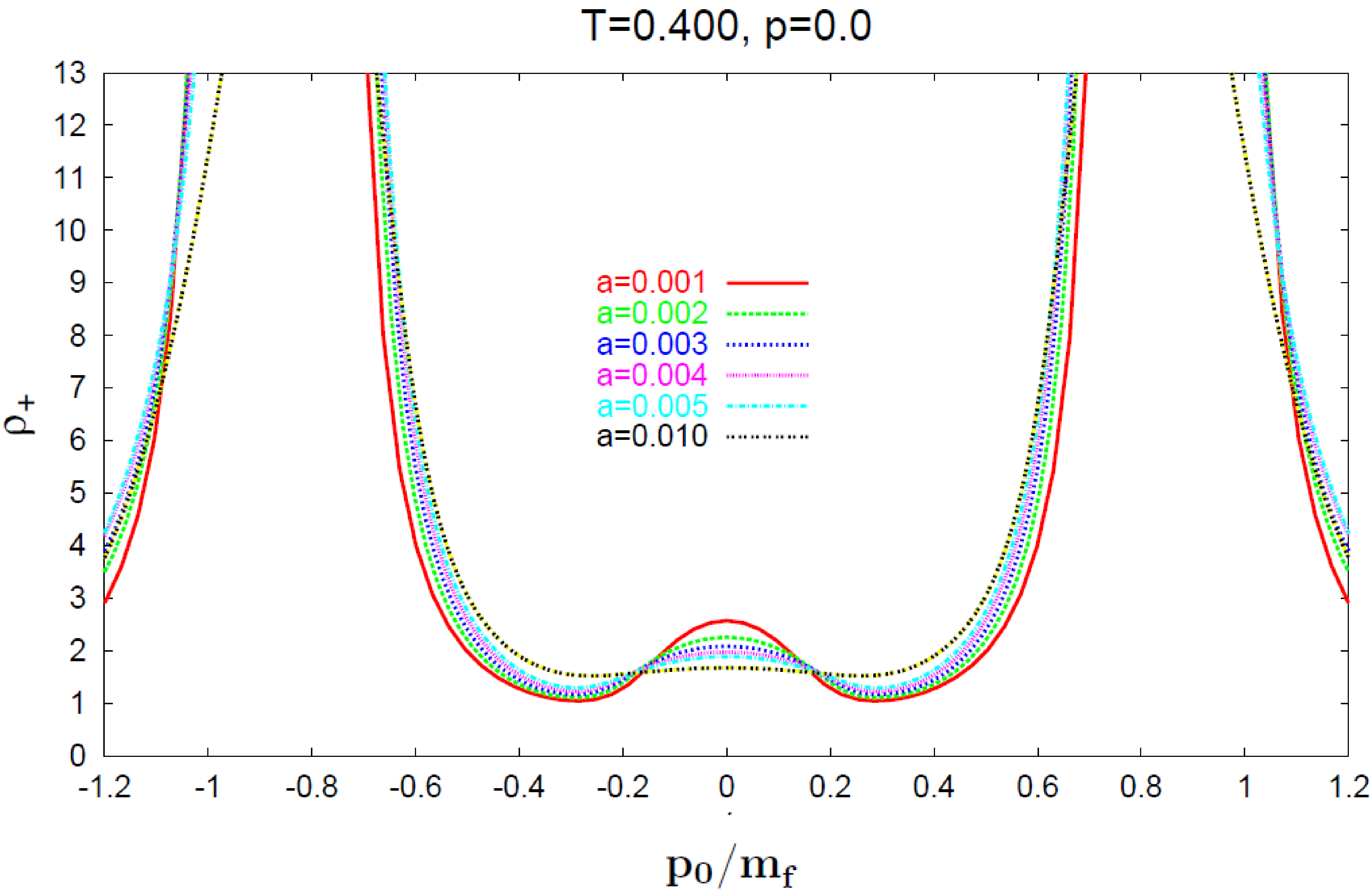
Decay Constant

$$\gamma(p)\sim\mathrm{Im}[D_+(p_0=\omega,p)]$$

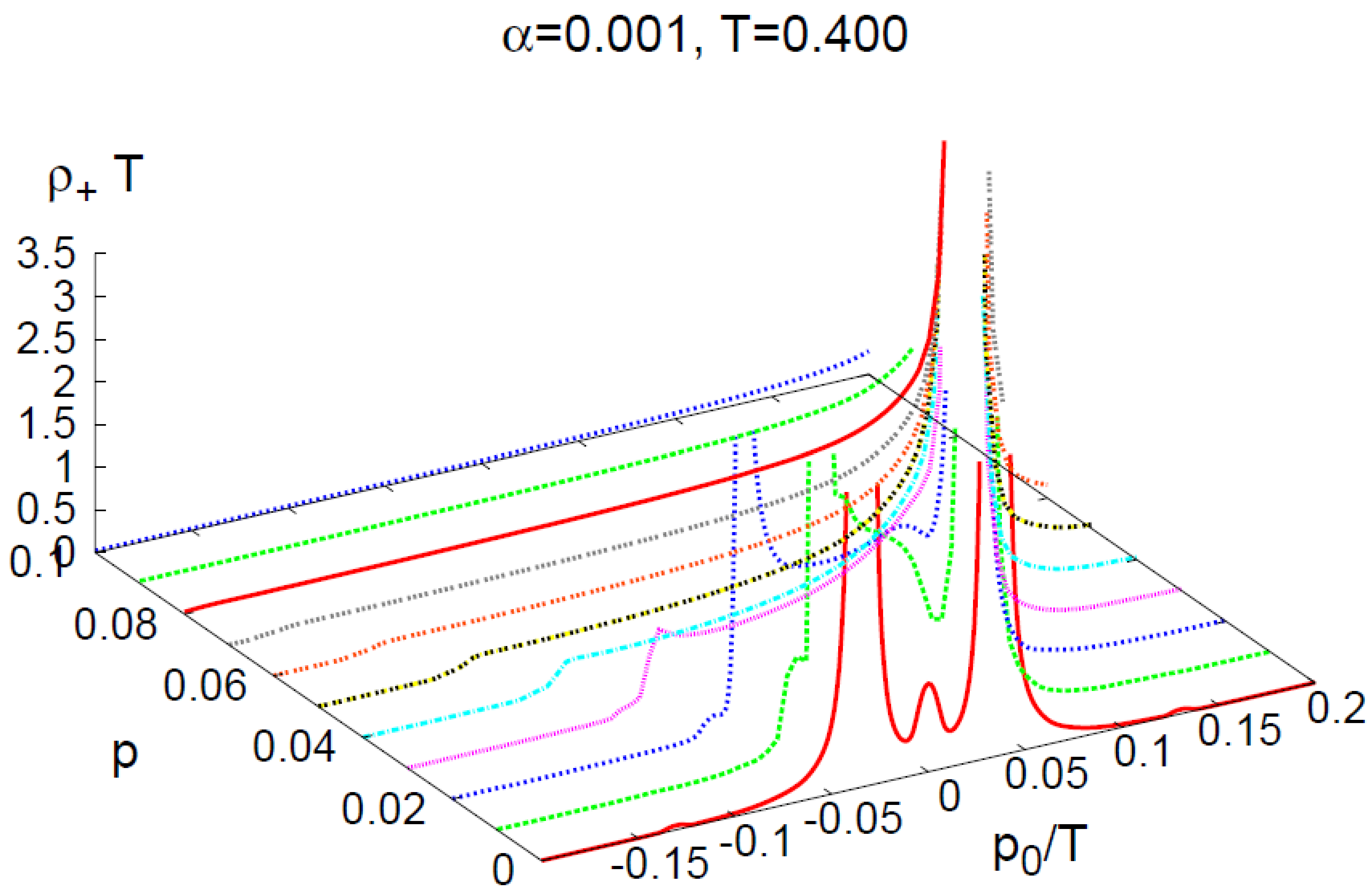
Spectral Function

$$\alpha = \frac{e^2}{4\pi}$$

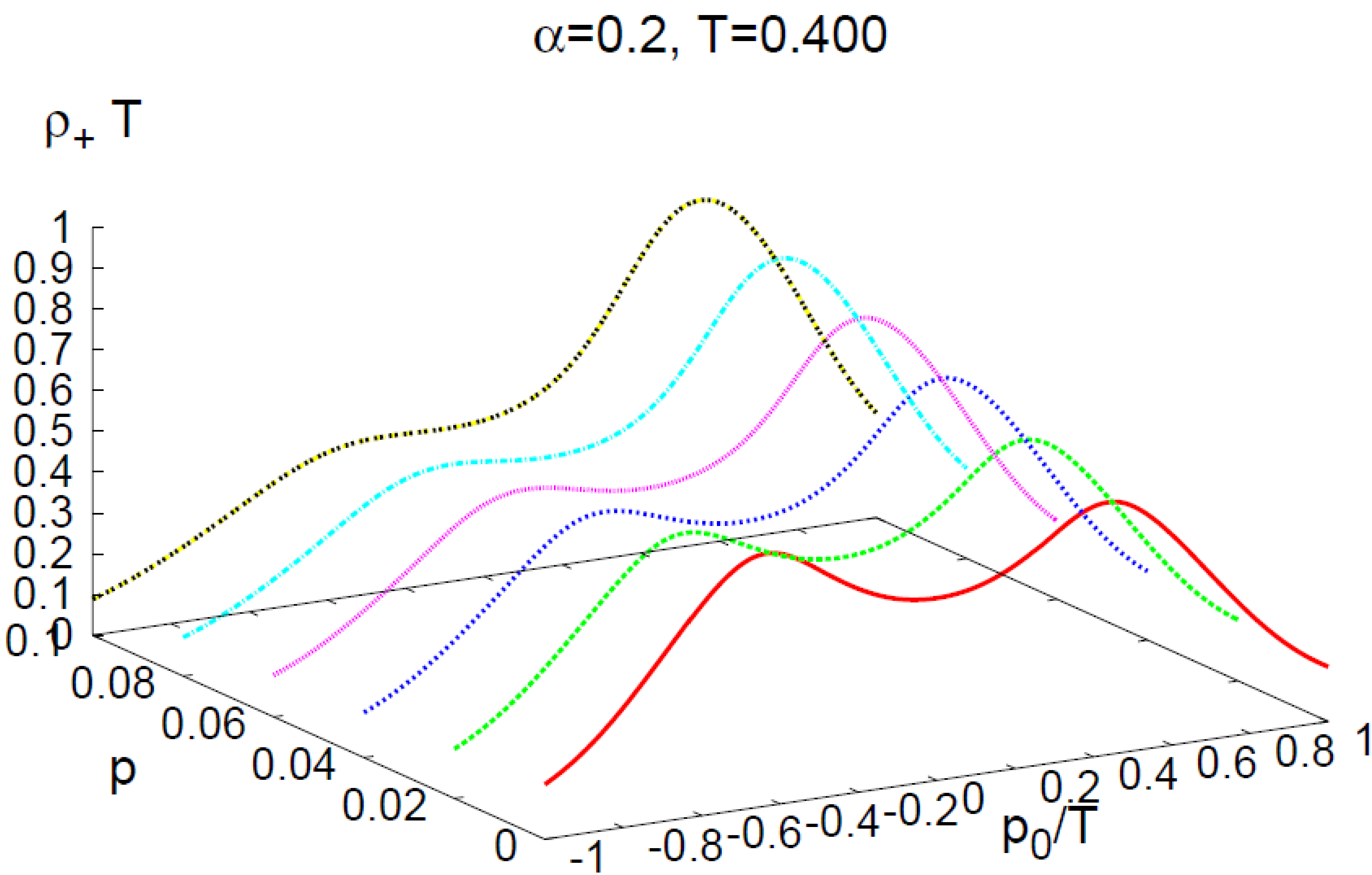




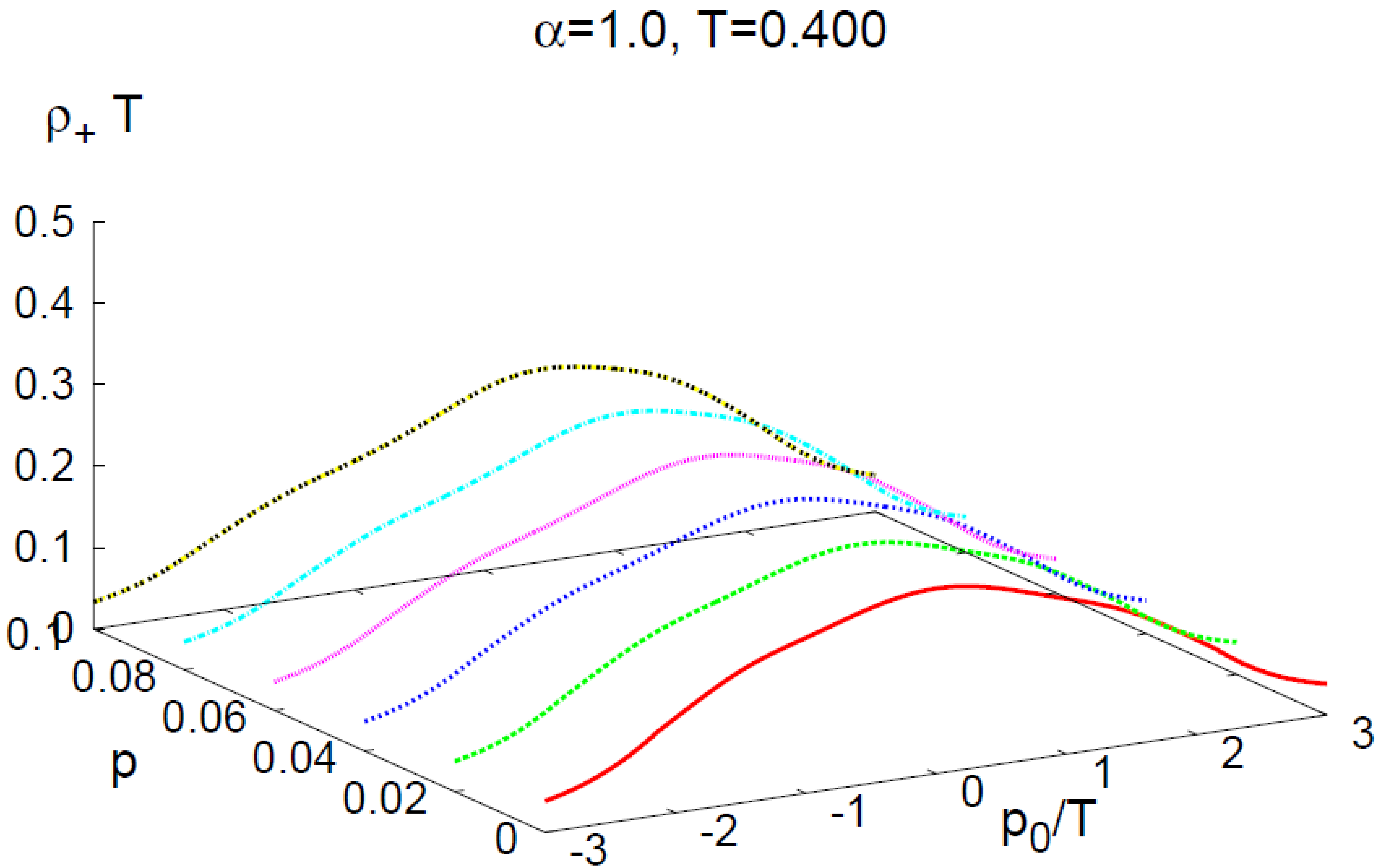
T=0.400, p=0.0
a=0.001
a=0.002
a=0.003
a=0.004
a=0.005
a=0.010
ρ_+
p_0/m_f
0
1
2
3
4
5
6
7
8
9
10
11
12
13
-1.2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
1.2



α=0.001, T=0.400
ρ+ T
3.5
3
2.5
2
1.5
1
0.5
0
0.1
0.08
0.06
0.04
0.02
0
p
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
p0/T



α=0.2, T=0.400
ρ+ T
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.08
0.06
0.04
0.02
0
p
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
p0/T



α=1.0, T=0.400
ρ+ T
0.5
0.4
0.3
0.2
0.1
0
0.1
0.08
0.06
0.04
0.02
0
p
-3
-2
-1
0
1
2
3
p0/T

Thermal Mass

Leading

$$m_f^2 = \frac{1}{8} e^2 T^2$$

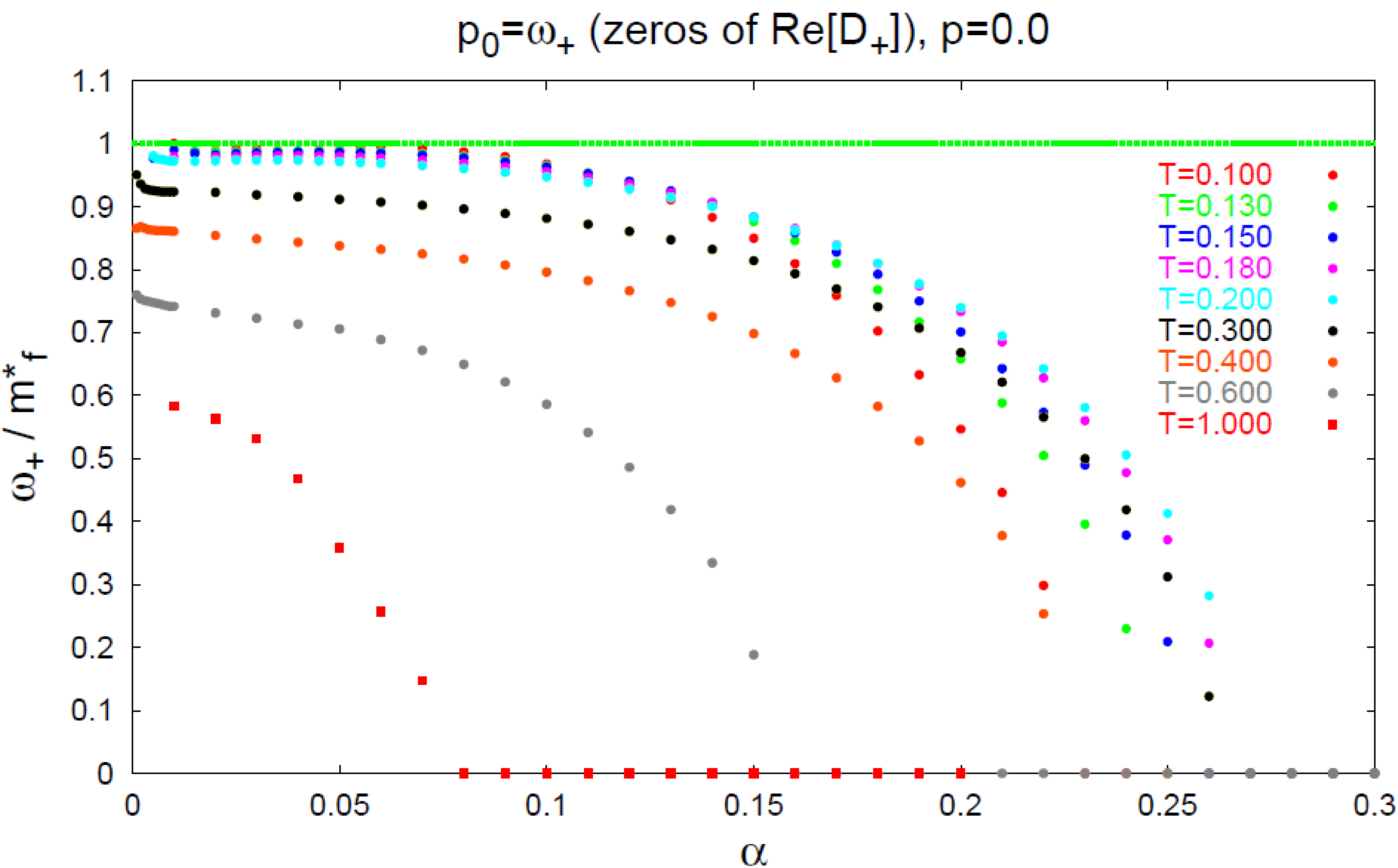
補正後

$$\left(\frac{m_f^*}{m_f}\right)^2 = 1 - \frac{4e}{\pi}\left[-\frac{e}{2\pi} + \sqrt{\frac{e^2}{4\pi^2} + \frac{1}{3}}\,\right]$$

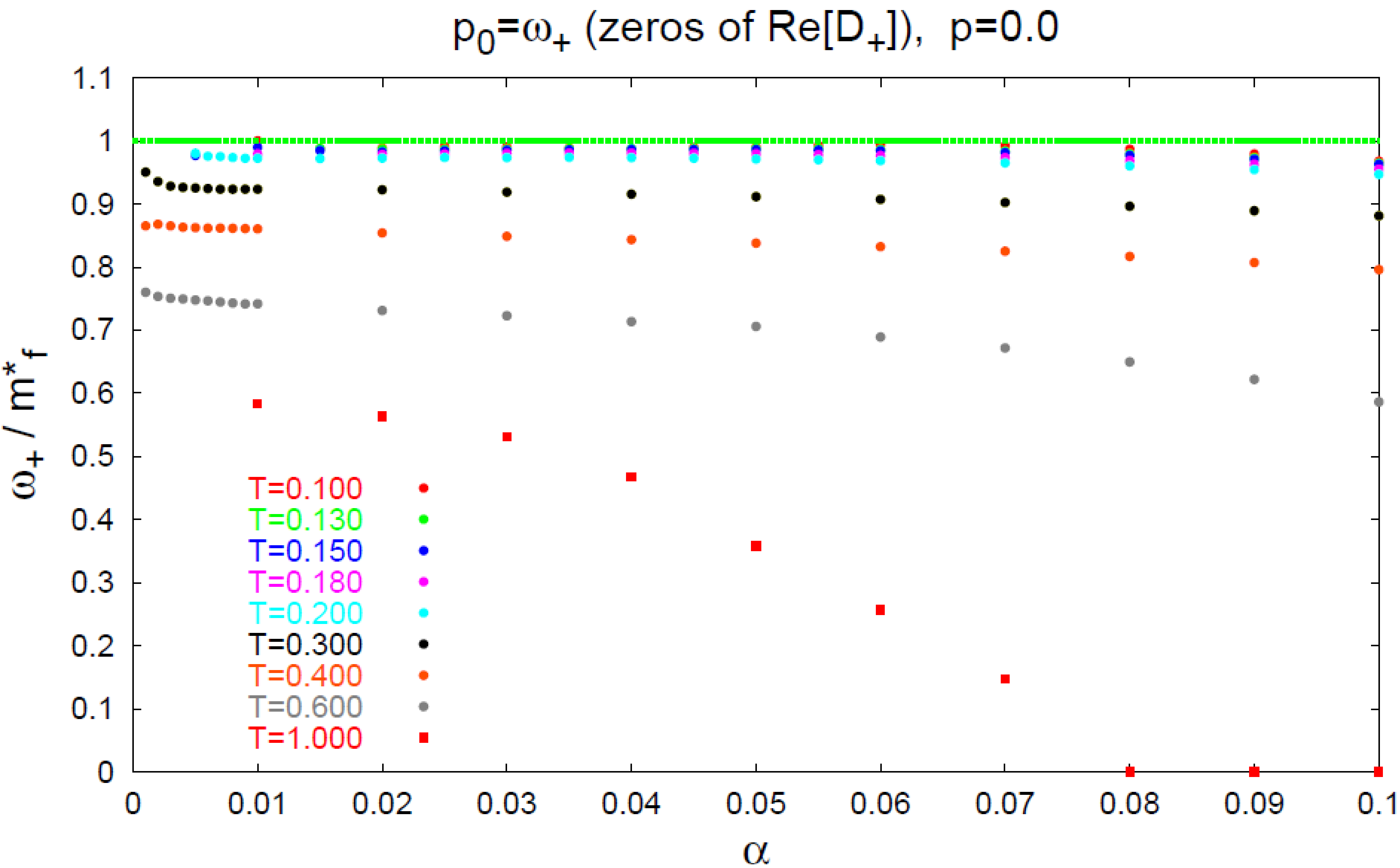
$$(m_D^*)^2 = m_D^2 - \frac{1}{\pi} e^2 T m_D^*$$

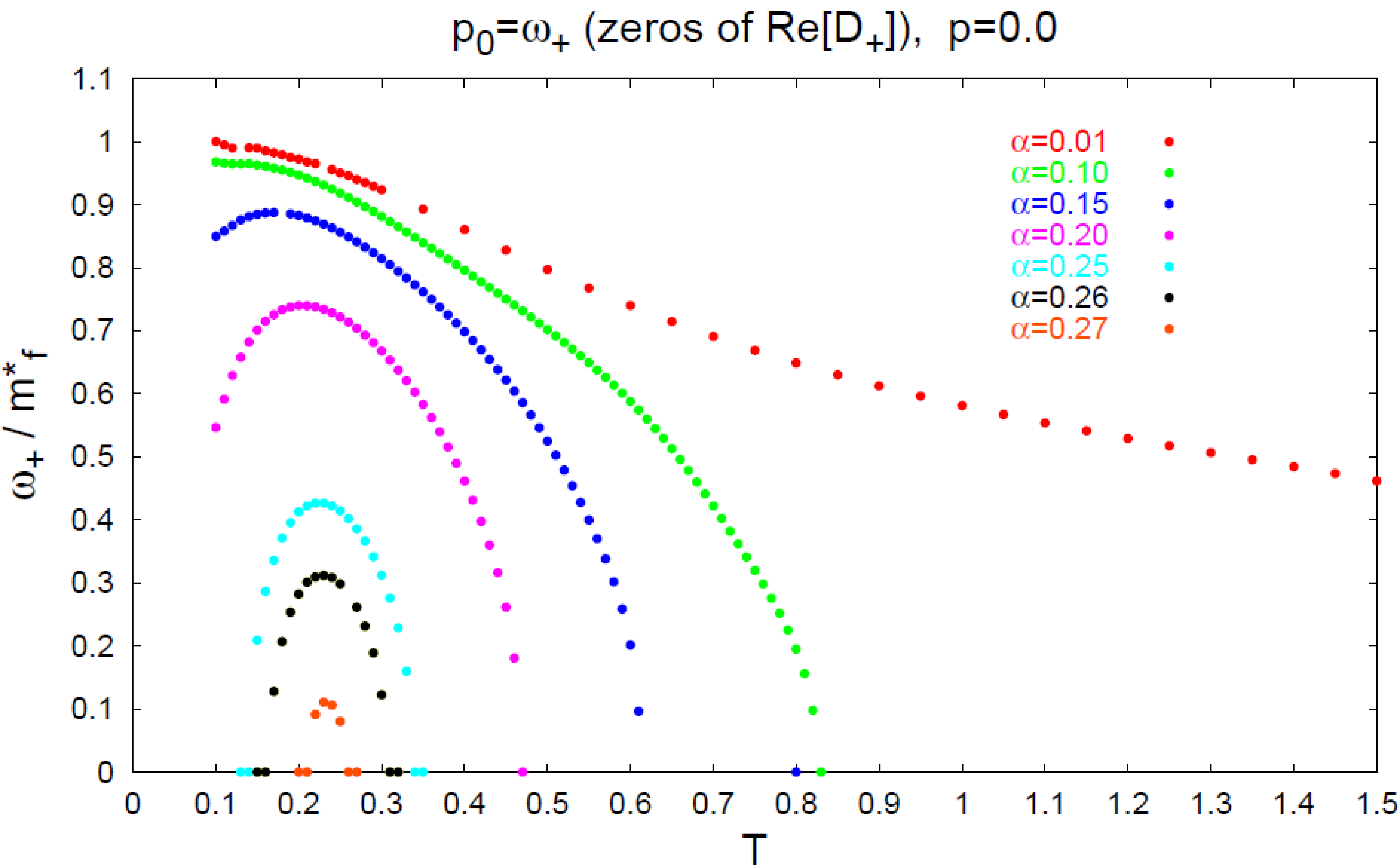
$$(m_f^*)^2 = m_f^2 - \frac{1}{2\pi} e^2 T m_D^*$$

$$\mathrm{Re}[D_+(p_0 = \omega, p = 0)] = 0$$



p0=ω+ (zeros of Re[D+]), p=0.0
ω+ / m*f
α
T=0.100
T=0.130
T=0.150
T=0.180
T=0.200
T=0.300
T=0.400
T=0.600
T=1.000
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.05
0.1
0.15
0.2
0.25
0.3

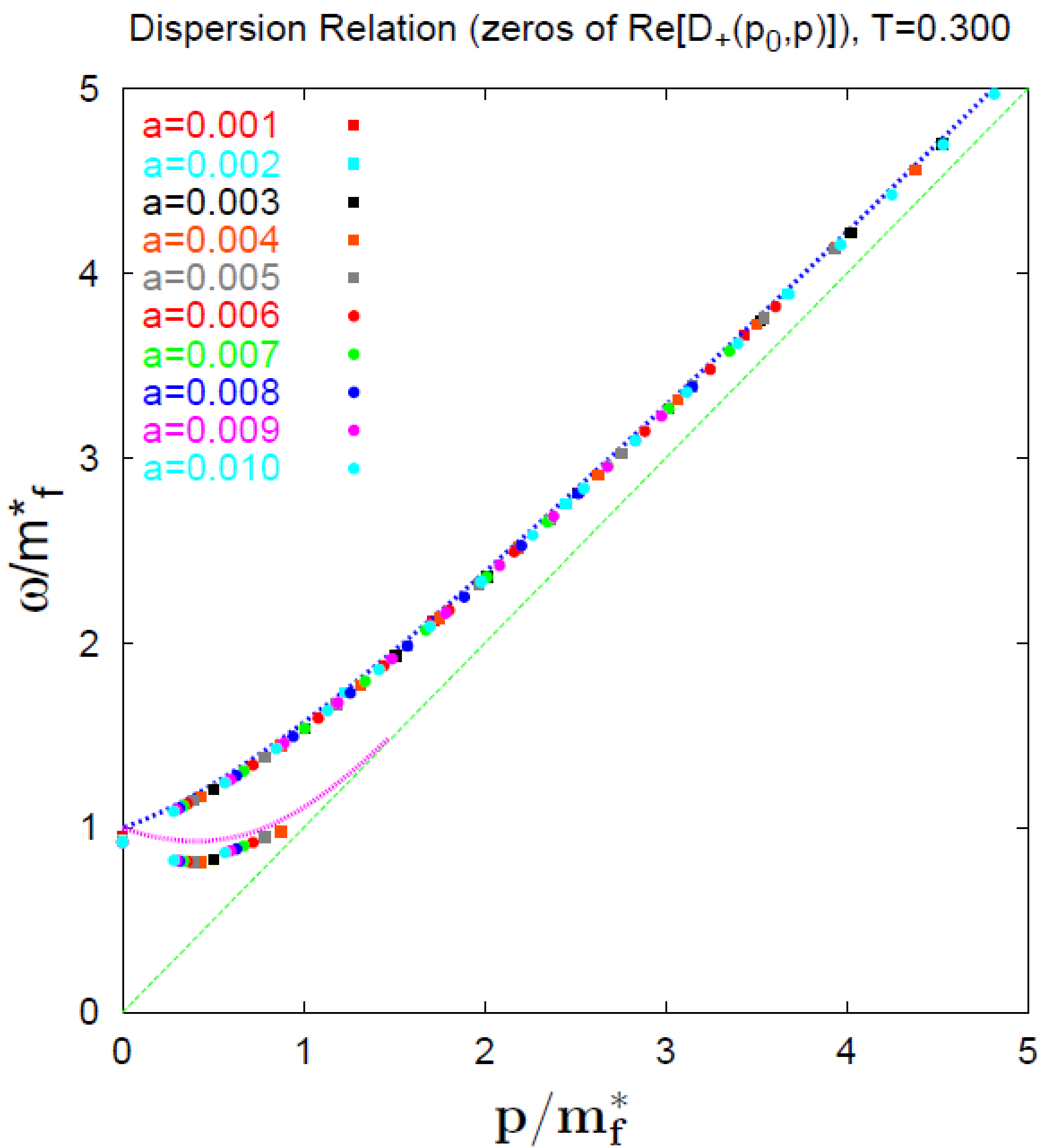

p0=ω+ (zeros of Re[D+]), p=0.0
ω+ / m*f
α
T=0.100
T=0.130
T=0.150
T=0.180
T=0.200
T=0.300
T=0.400
T=0.600
T=1.000
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1



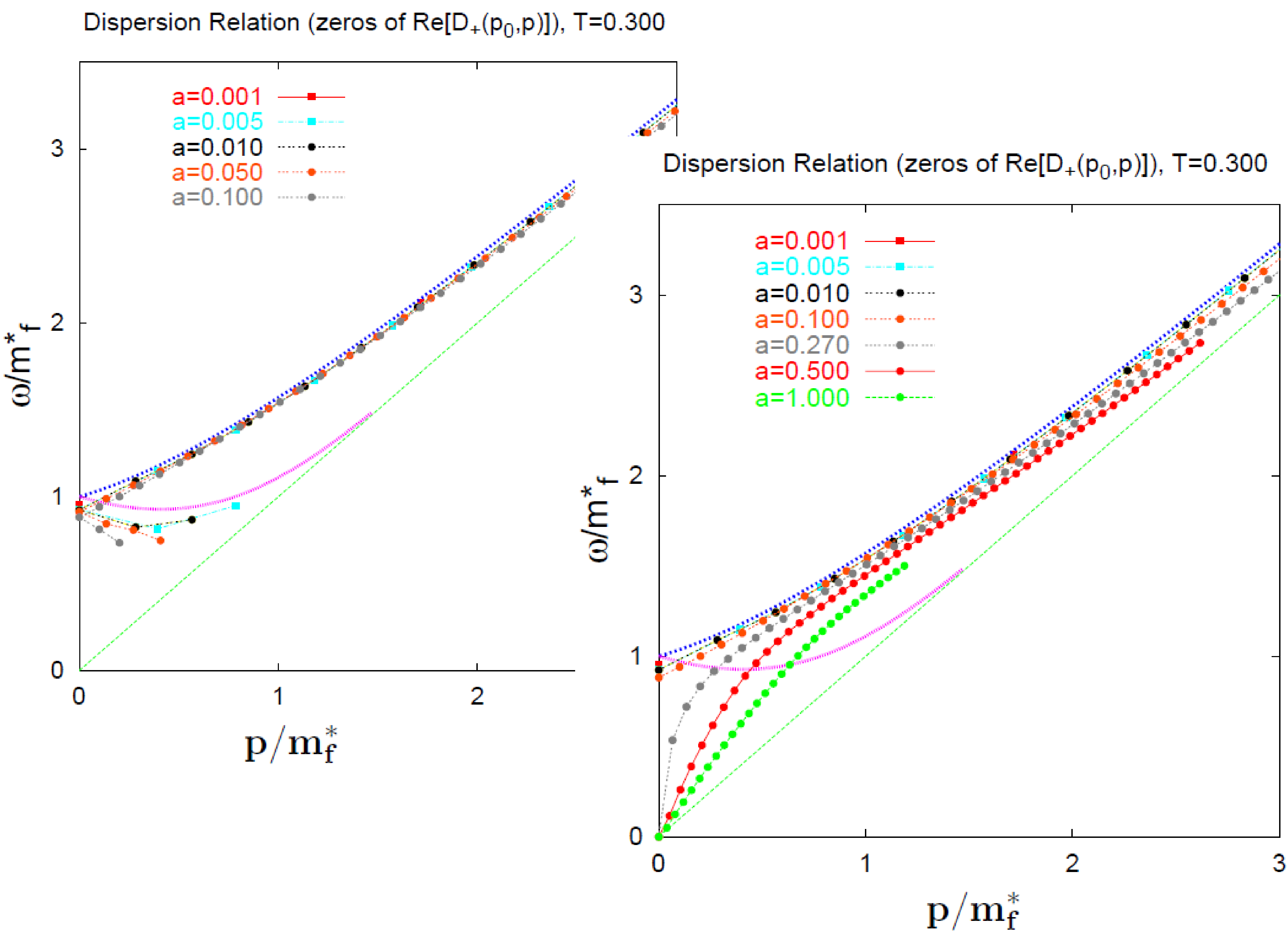
p0=ω+ (zeros of Re[D+]), p=0.0
α=0.01
α=0.10
α=0.15
α=0.20
α=0.25
α=0.26
α=0.27
ω+ / m*f
T

Dispersion relation

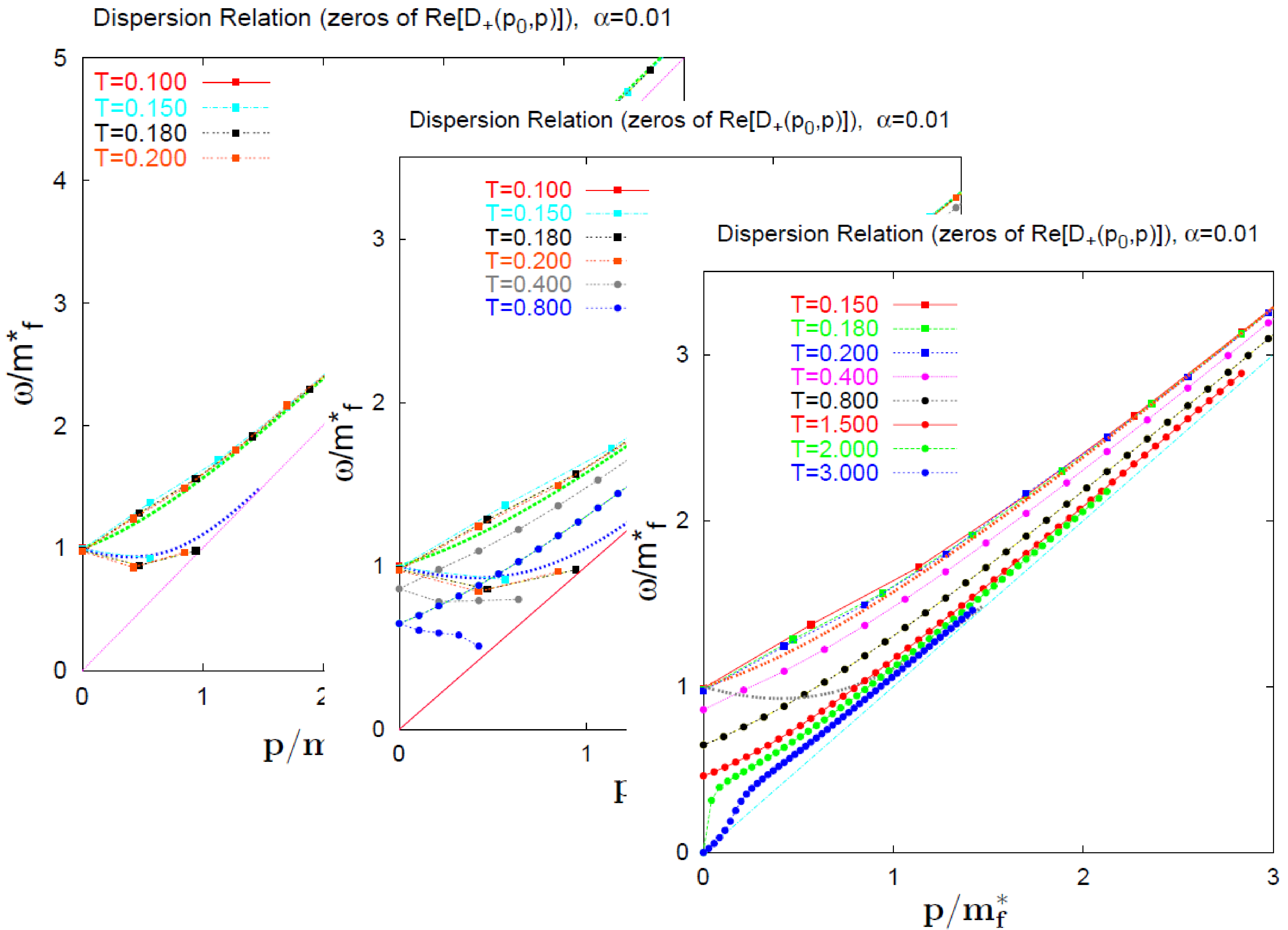
$$\mathrm{Re}[D_+(p_0 = \omega, p)] = 0$$



small coupling のとき
HTLの振る舞いを再現
している

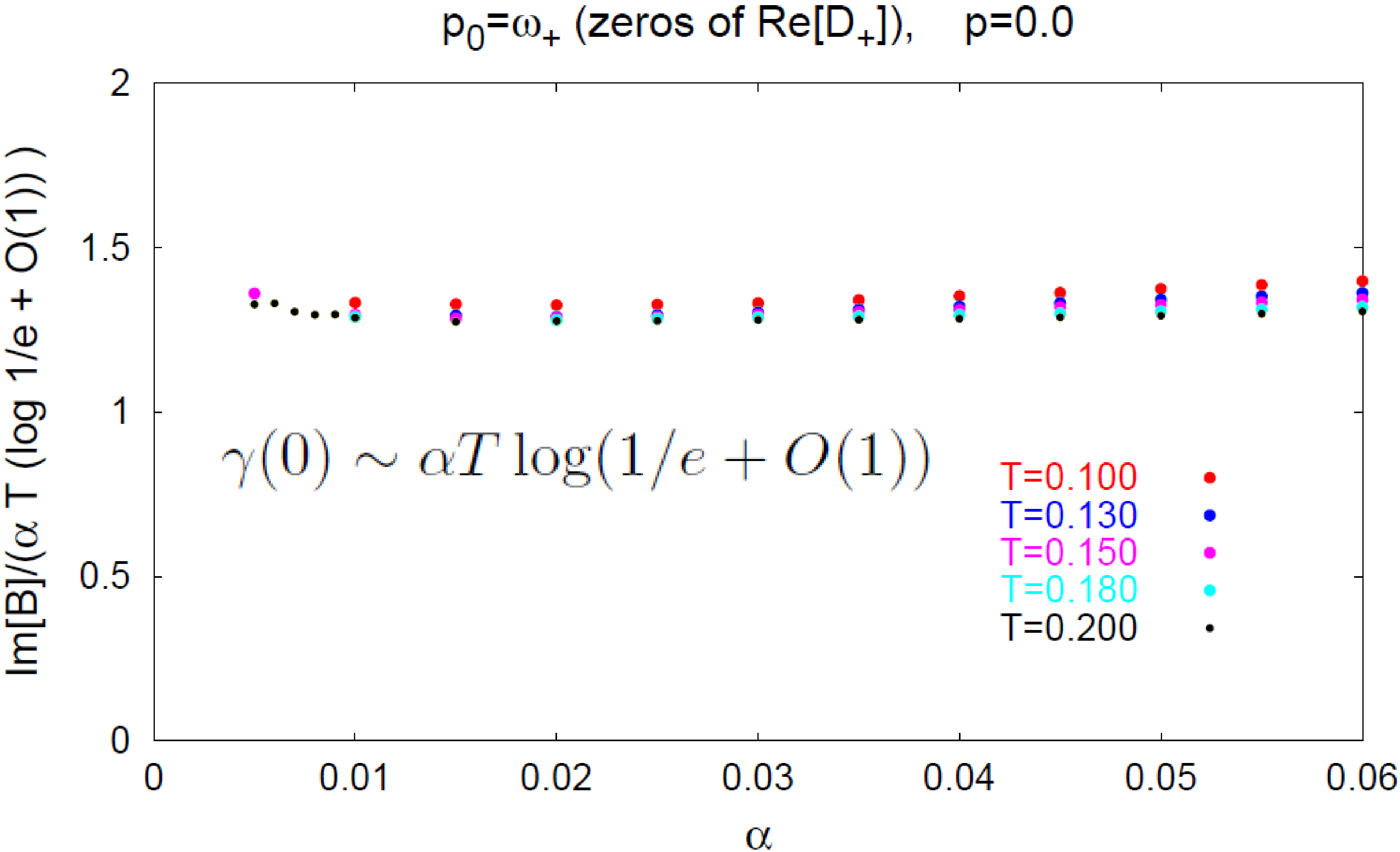


Dispersion Relation (zeros of Re[D+(p0,p)]), T=0.300
a=0.001
a=0.005
a=0.010
a=0.050
a=0.100
ω/m*f
p/m*f
Dispersion Relation (zeros of Re[D+(p0,p)]), T=0.300
a=0.001
a=0.005
a=0.010
a=0.100
a=0.270
a=0.500
a=1.000
ω/m*f
p/m*f



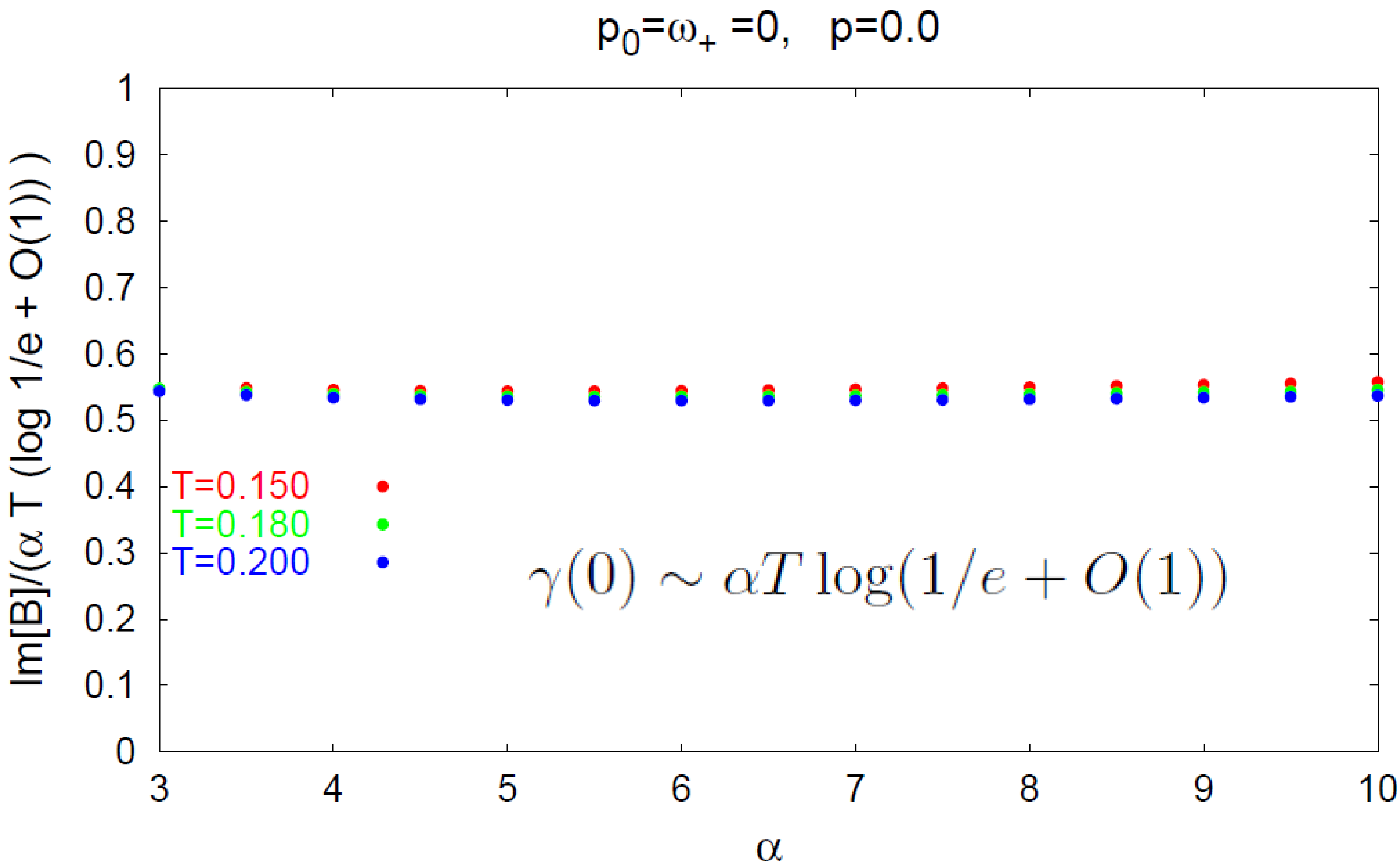
Dispersion Relation (zeros of Re[D+(p0,p)]), α=0.01
T=0.100
T=0.150
T=0.180
T=0.200
ω/m*f
p/m
Dispersion Relation (zeros of Re[D+(p0,p)]), α=0.01
T=0.100
T=0.150
T=0.180
T=0.200
T=0.400
T=0.800
ω/m*f
Dispersion Relation (zeros of Re[D+(p0,p)]), α=0.01
T=0.150
T=0.180
T=0.200
T=0.400
T=0.800
T=1.500
T=2.000
T=3.000
ω/m*f
p/m*f

Small Coupling での Decay Constant



HTLでの振る舞いを再現

Large Coupling での Decay constant



Small α とは 係数およびO(1)の値が異なる

まとめ（主な結論）

- small αでは、（T≦0.2のとき）HTLの振る舞いを再現する
- small αで、p～0のとき ρに 3rd peak が存在する
  $\mathrm{Im}[D_+(p_0=\omega,p)]$ が大きいためsuppressされる
- large α または large Tでは
  熱的質量が小さくなり、最終的に0となる
- Decay constant は、（T=0.1～0.2の範囲で）
  small α および large α でともに
  $$\gamma(0) \sim \alpha T \log(1/e + O(1))$$
  と同じ振る舞いを示す（ただし、つながらない）

今後

Running Coupling（QCD） & μ≠0 での解析（実行中）