Moduli Stabilisation in the Presence of Matter Fields

Lisa Hall
University of Sheffield, UK

work in progress with
Carsten van de Bruck
and Ki-Young Choi

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- Uplifting of AdS vacua

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- Matter Superpotentials: (F-term uplifting)
  - **Lebedev,Nilles,Ratz (2006)**
- Stabilisation from additional matter field
  - (with background fluid)

KKLT (Kachru, Kalosh, Linde, Trivedi) Model

Kähler potential: $K = -3\ln\left(T + \bar{T}\right)$

Superpotential: $W = W_0 + Ae^{-aT}$

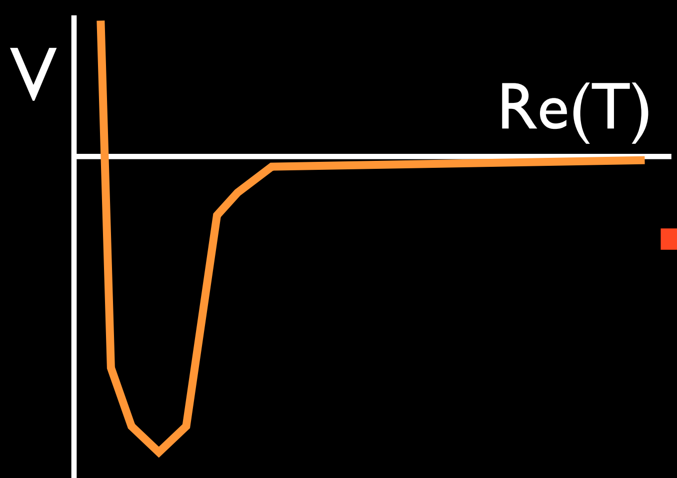
integrate out complex-structure moduli

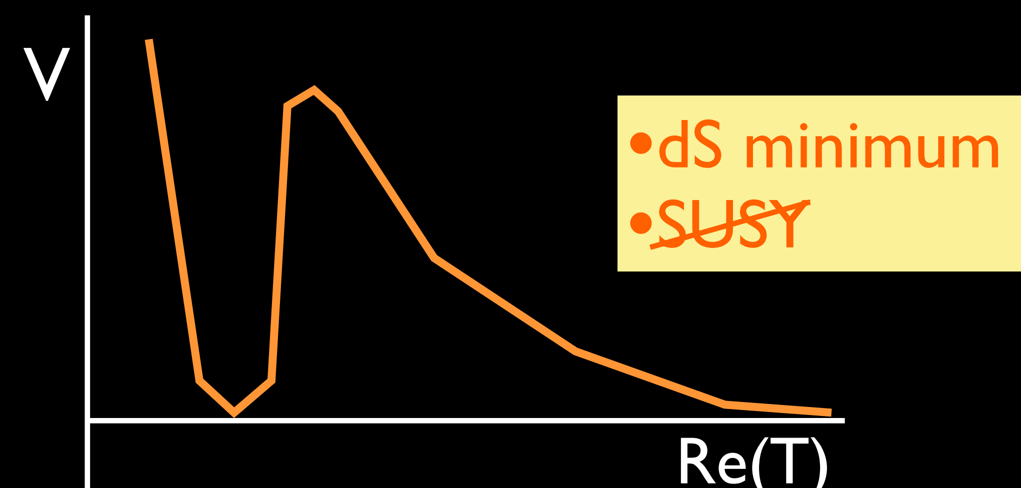
non-perturb. corrections
e.g. Witten (1996)

$$V = e^{K}\left(K^{i\bar{j}} D_i W \overline{D_j W} - 3W\overline{W}\right)$$

AdS minimum

Add $\overline{\text{D3}}$-brane: $\delta V = \frac{k}{\mathrm{Re}(T)^2}$





KKLT and the Polonyi Model

Lebedev,Nilles,Ratz (2006)

Lebedev,Löwen,Mambrini,Nilles,Ratz (2006)

$$K = -3\ln\left(T+\bar{T}\right) + |C|^2$$

$$\mathcal{W}(C) = c + \mu^2 C$$

$$\mathcal{W}(T) = W_0 + Ae^{-\alpha T}$$

$$V_0 \sim \epsilon\mu^4 \qquad c \sim \mu^2\left(2-\sqrt{3}-\frac{\sqrt{3}}{6}\epsilon\right)$$

$$\mu^2 \sim W_0$$

modulus heavy compared to Polonyi field

$$C \sim \sqrt{3}-1-\frac{\sqrt{3}-3}{6}\epsilon$$

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$$C \sim \sqrt{3} - 1 - \frac{\sqrt{3}-3}{6}\epsilon$$

$$C = C_r + iC_i \qquad T = T_r + iT_i \qquad \phi = \sqrt{\frac{3}{2}}\ln T_r$$

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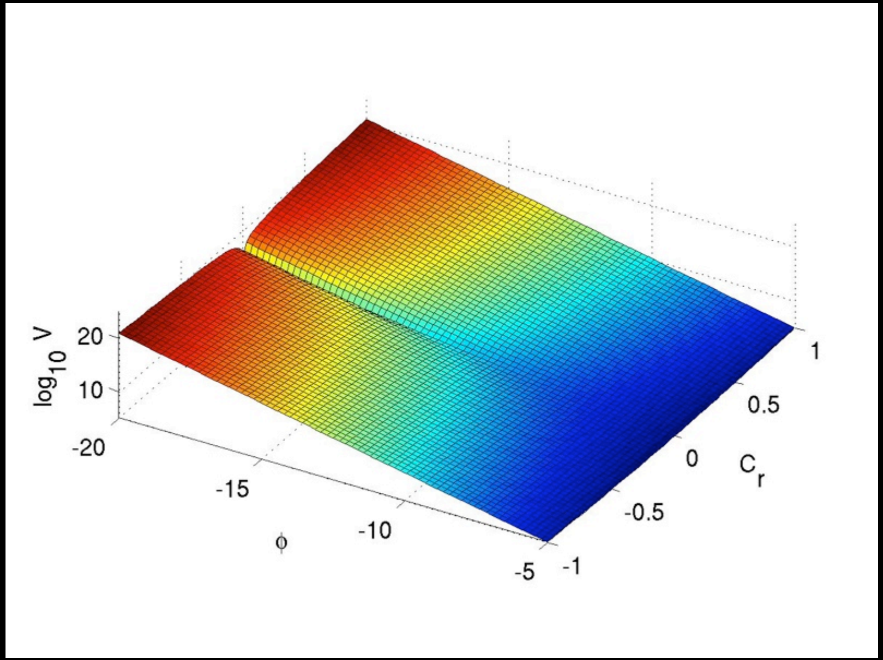
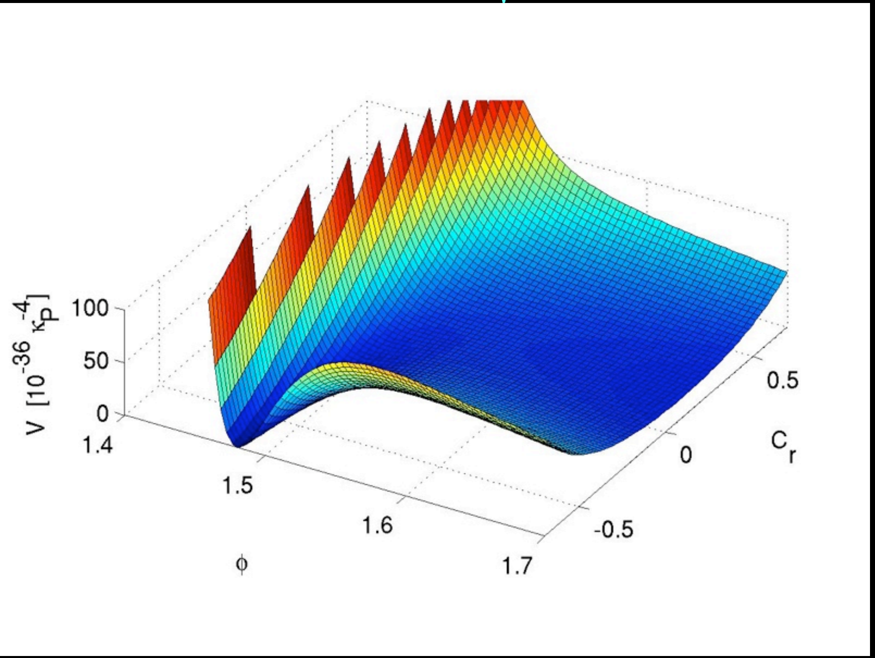


A=1

α=12

$\mu^2=10^{-8}$



Single Field Dynamics

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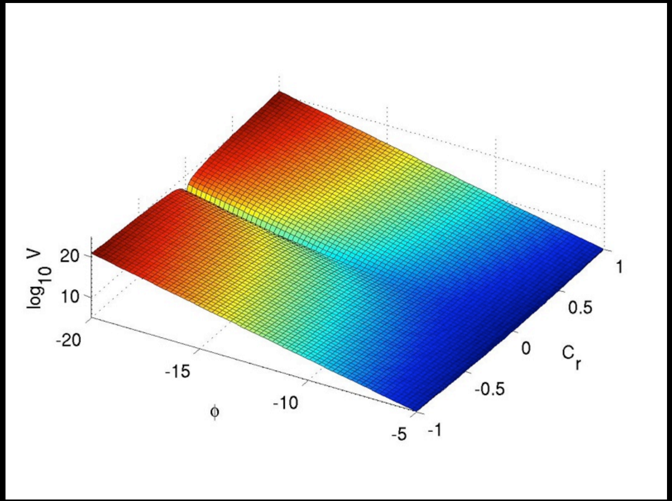
$$C_i = T_i = 0$$

$$C_r(N = 0) = 0$$



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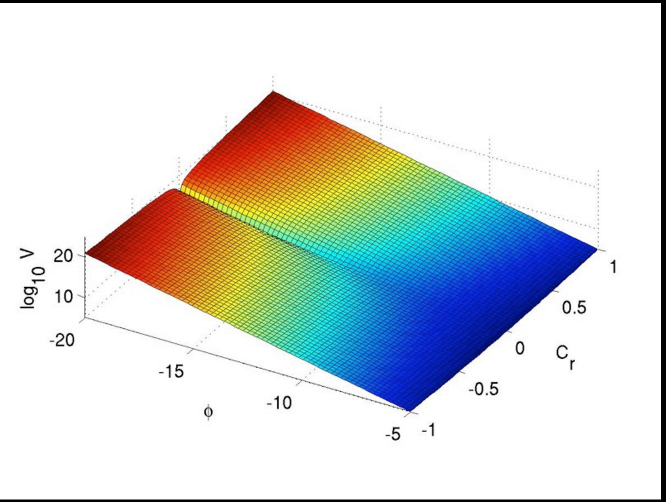

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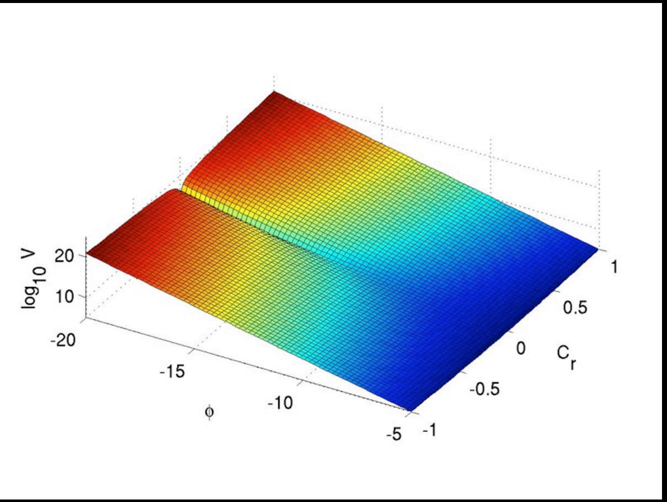
matter
background field



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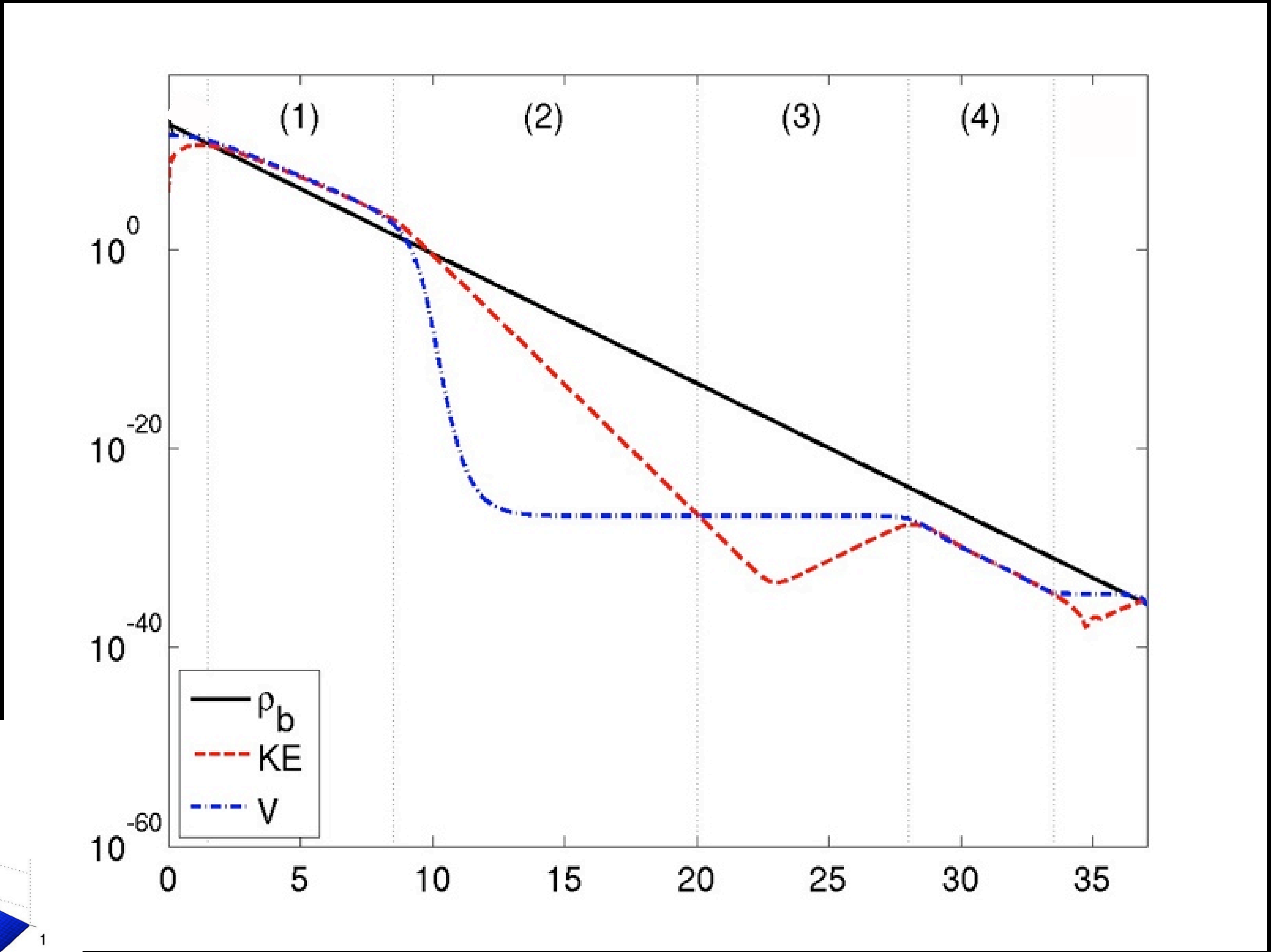

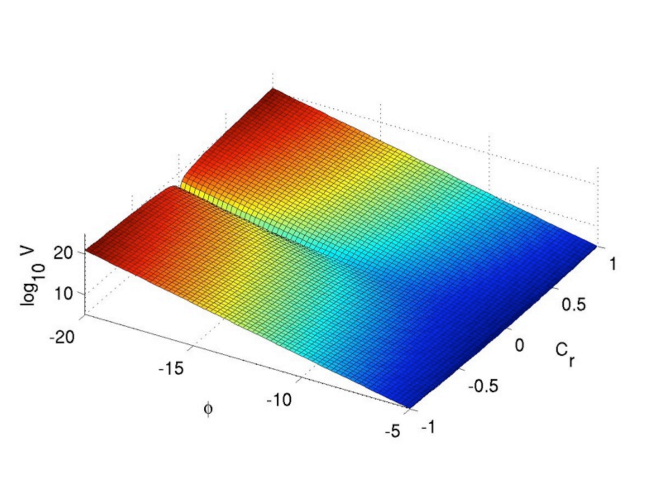

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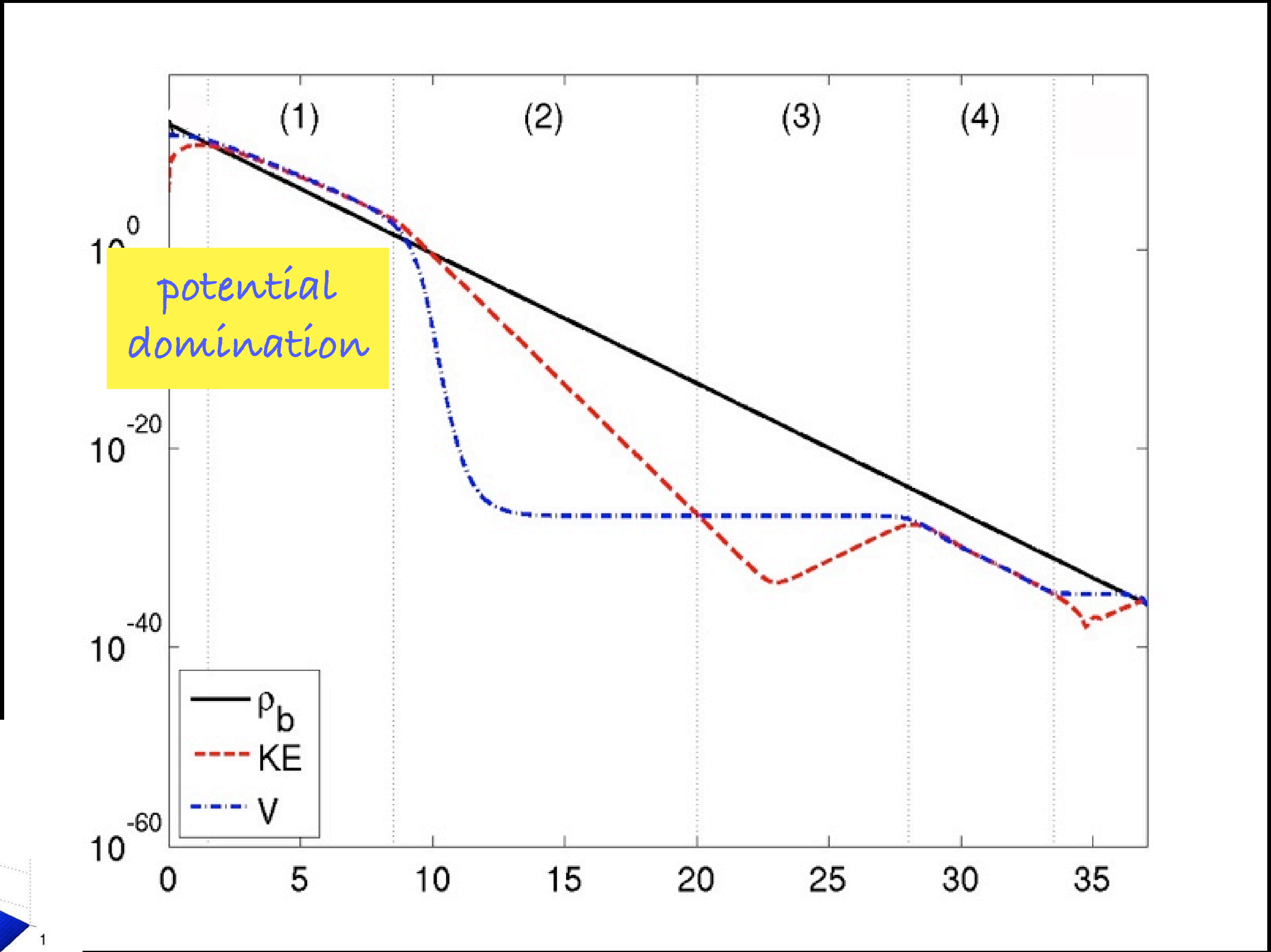

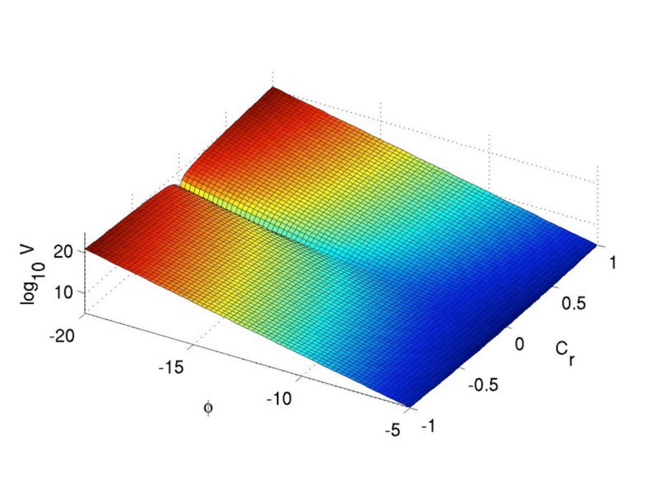

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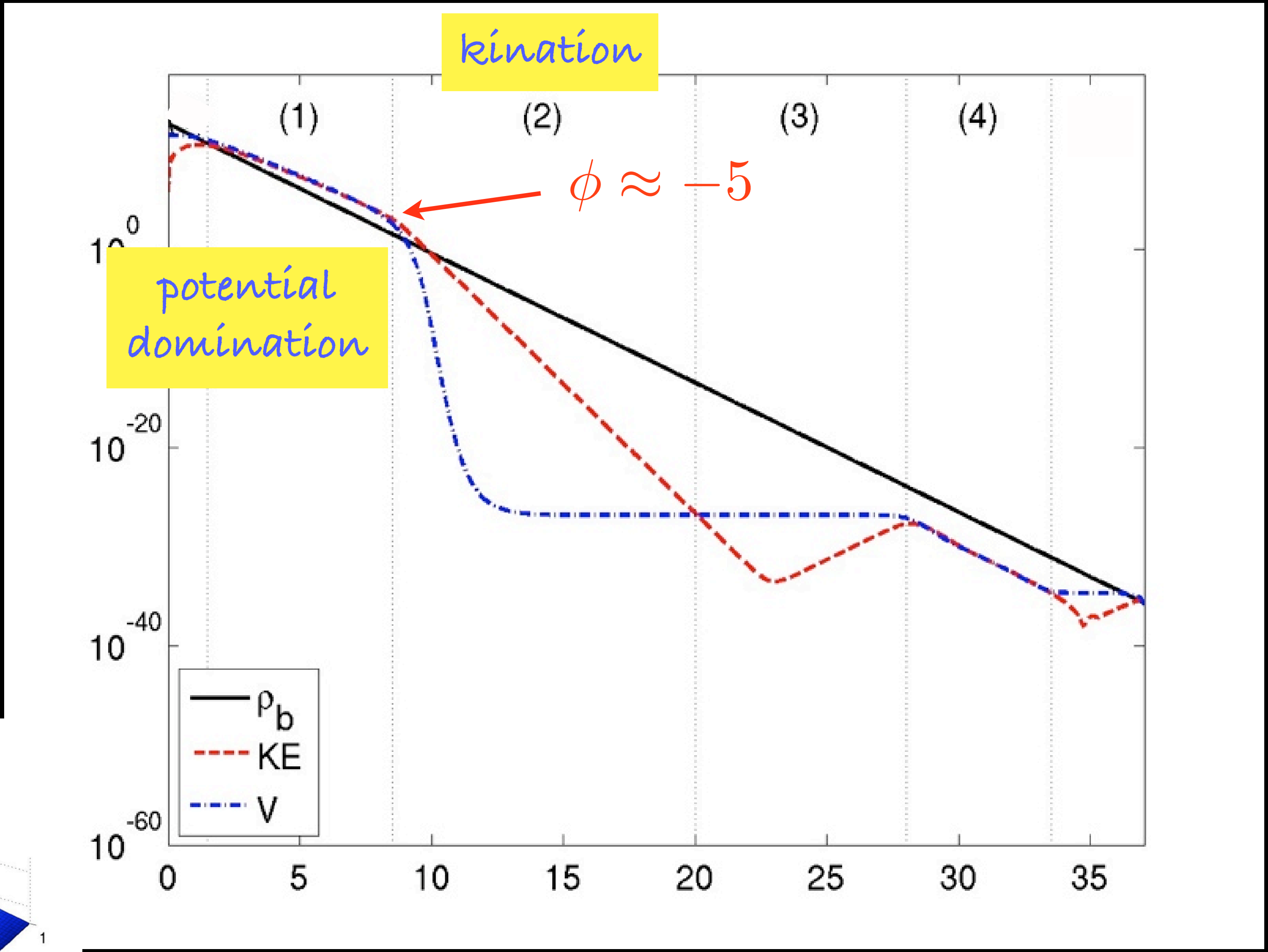

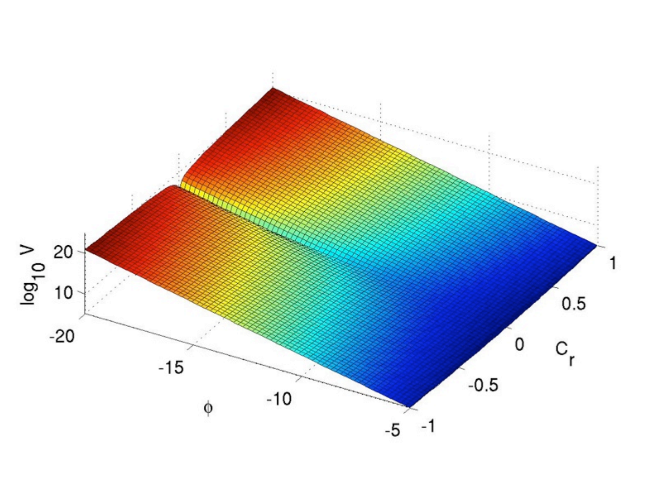

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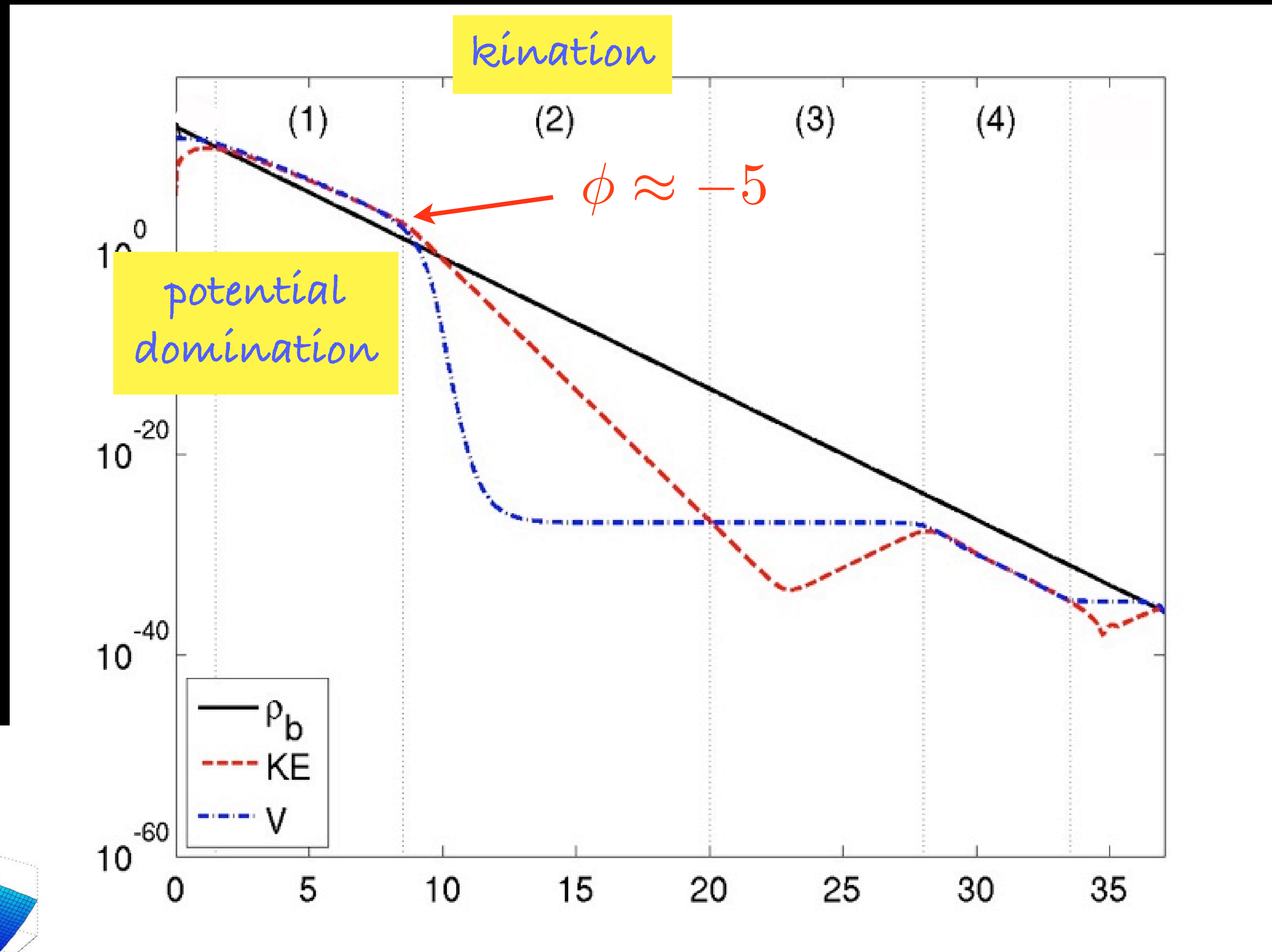

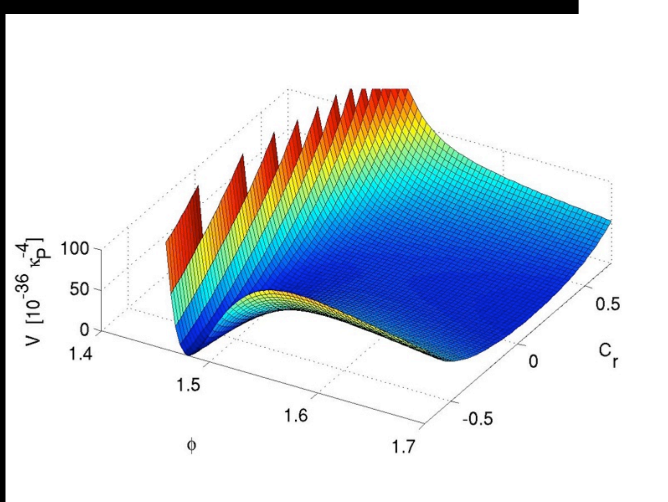

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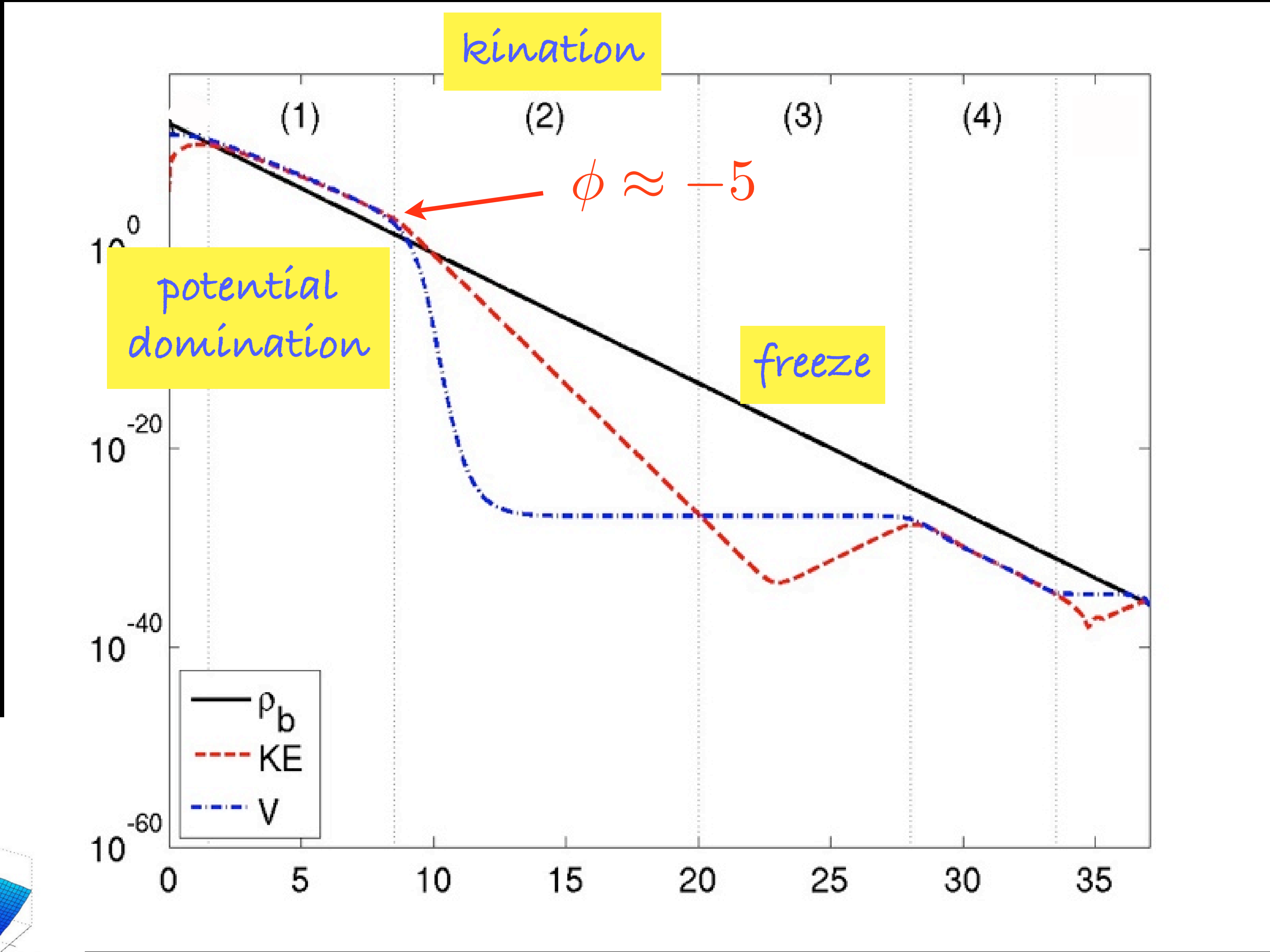

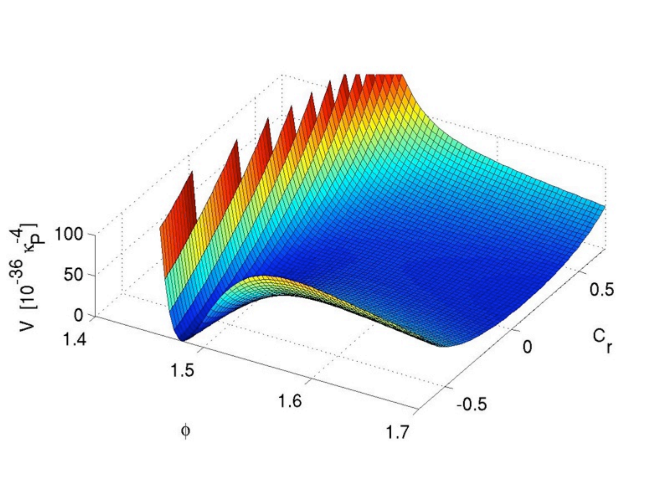

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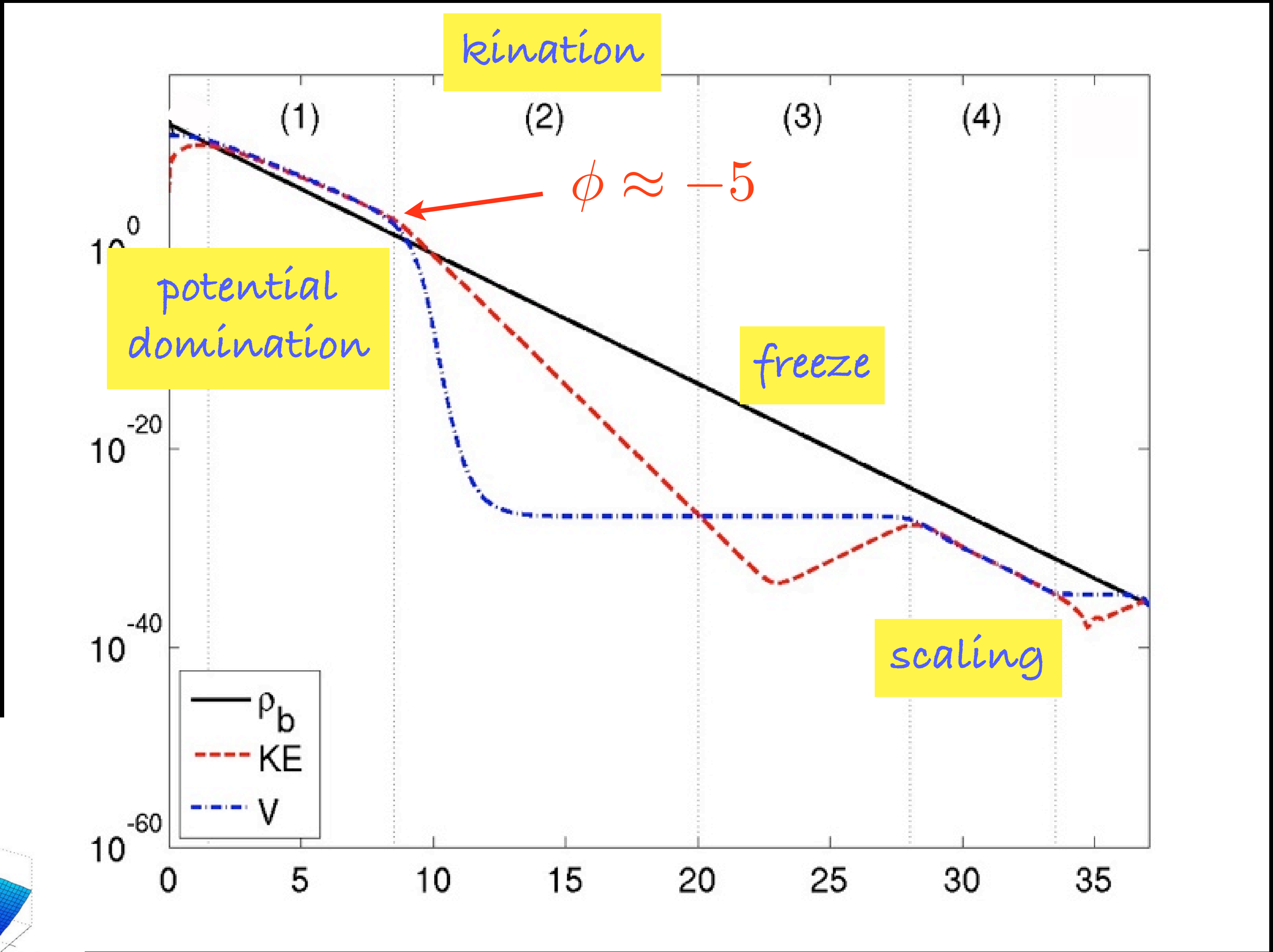

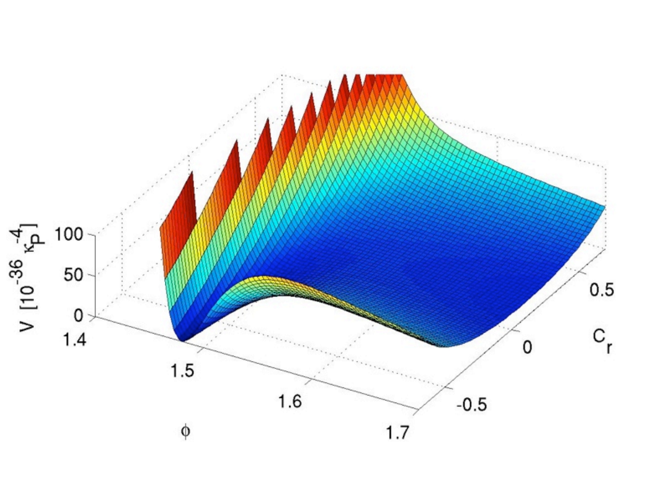

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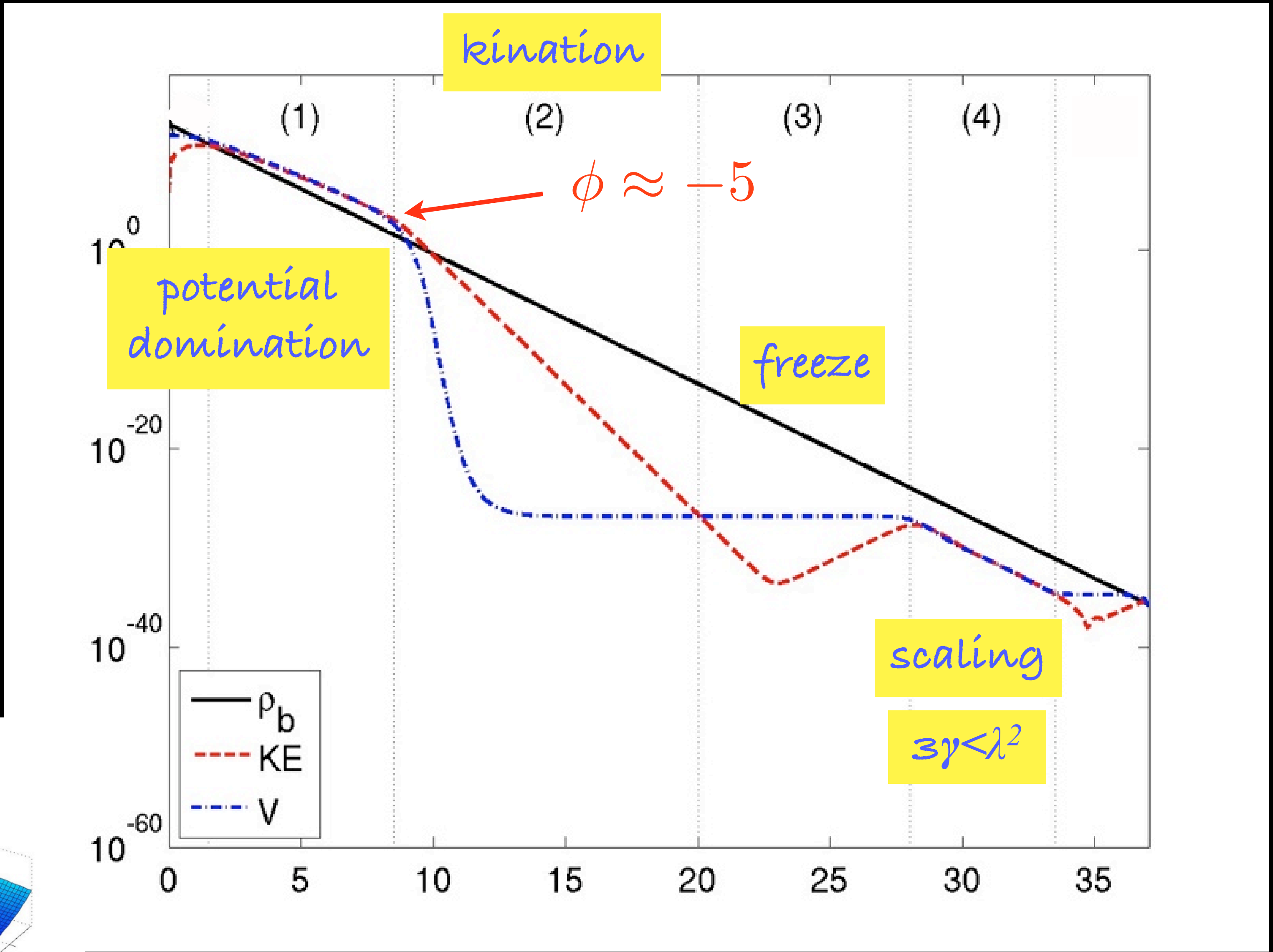

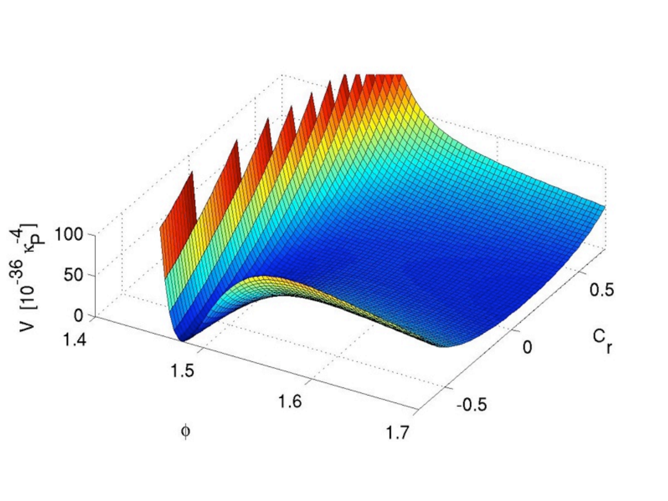

$$\lambda \equiv -\frac{1}{V}\frac{\partial V}{\partial \phi}$$

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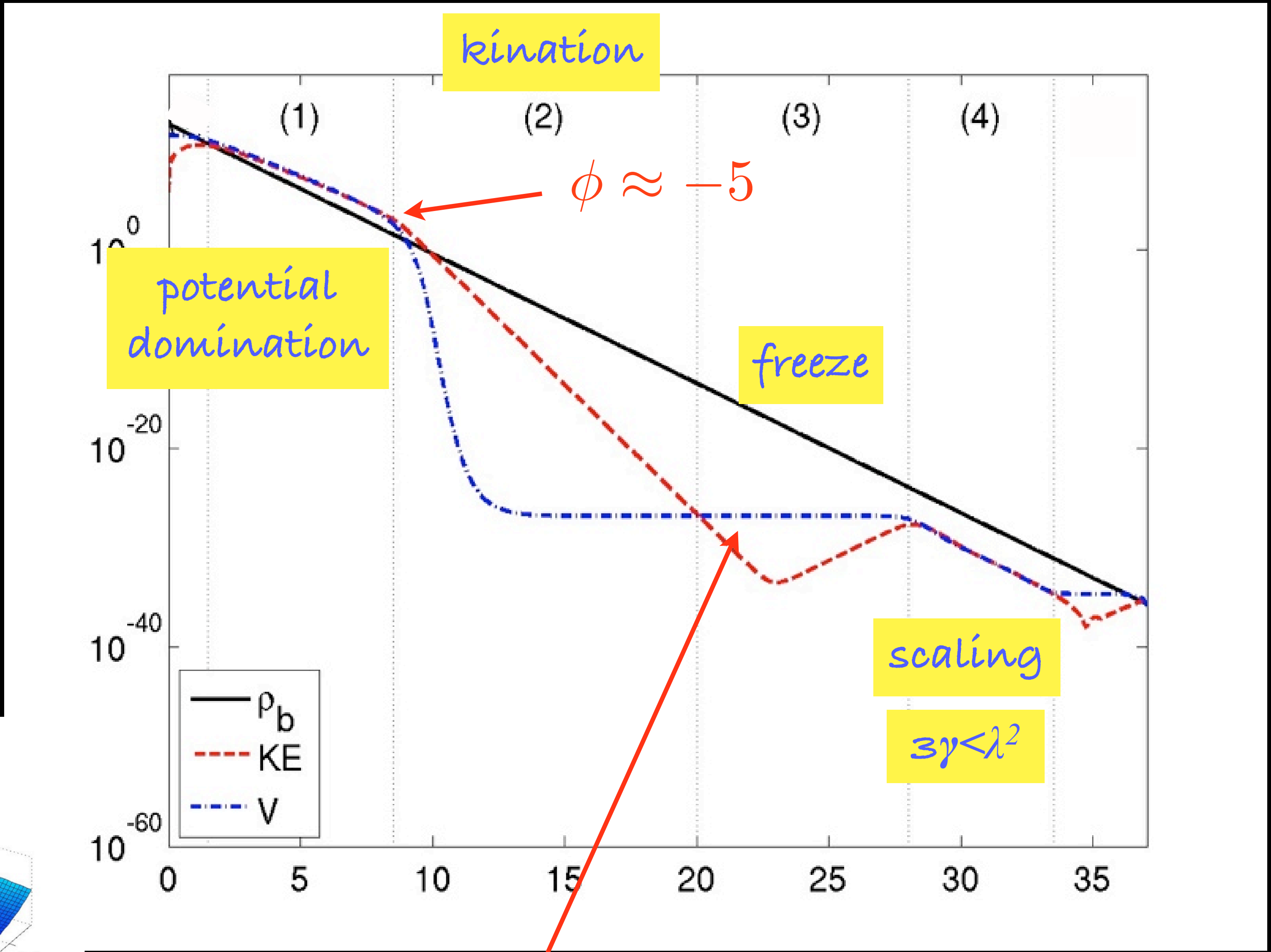
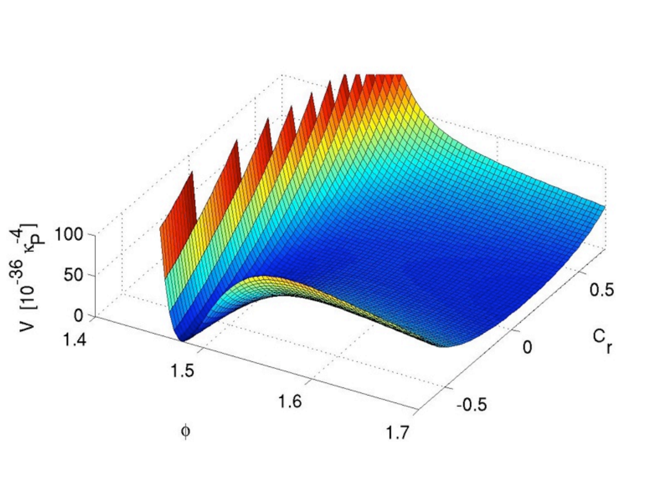




stabilisation depends on freeze point

$$\lambda \equiv -\frac{1}{V}\frac{\partial V}{\partial \phi}$$

$C_i = T_i = 0$

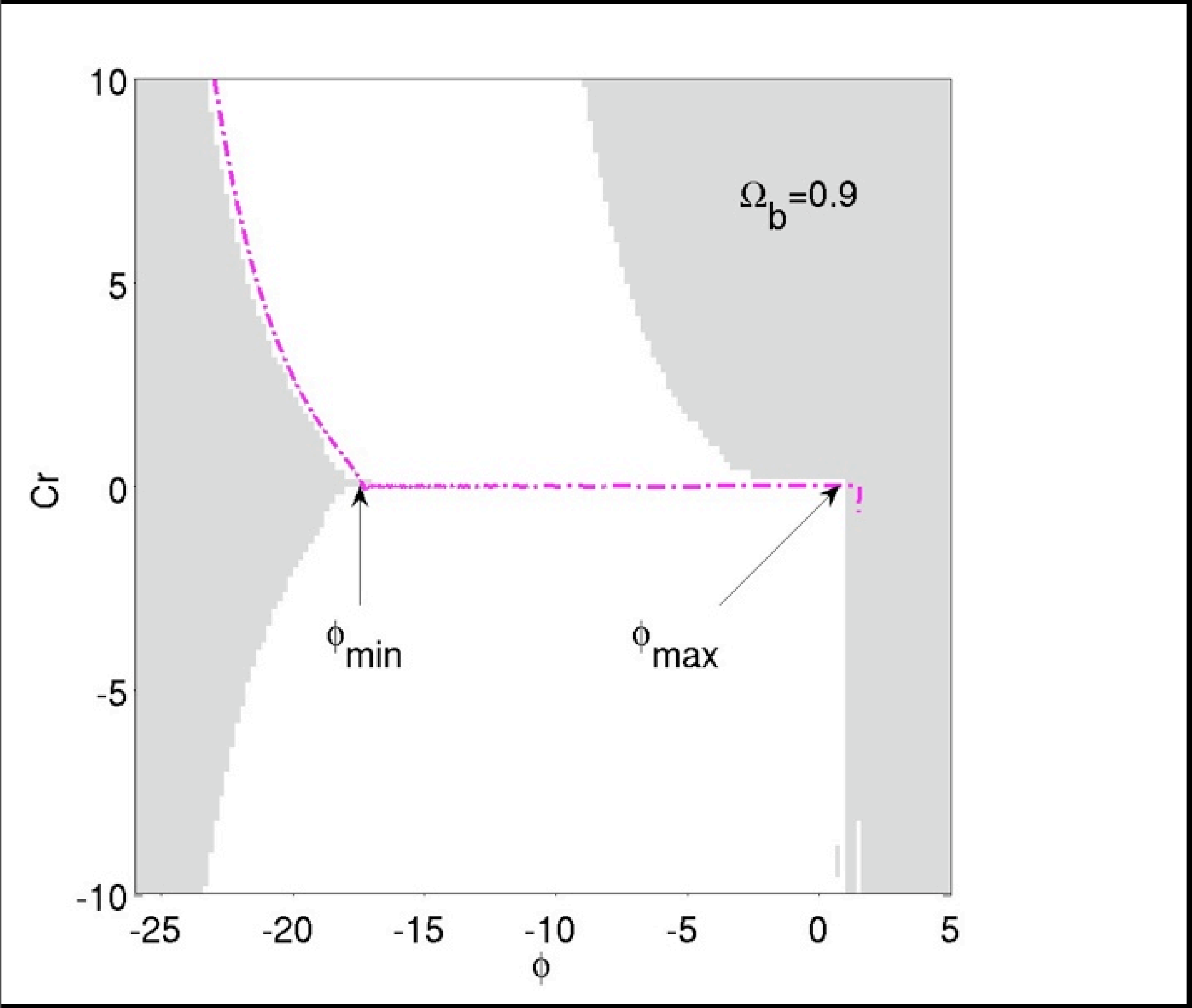
Two REAL Fields

$\boldsymbol{\Omega_{\mathrm{b}} = 0.9}$

$C_i = T_i = 0$

Two REAL Fields

$\mathbf{\Omega_b = 0.9}$



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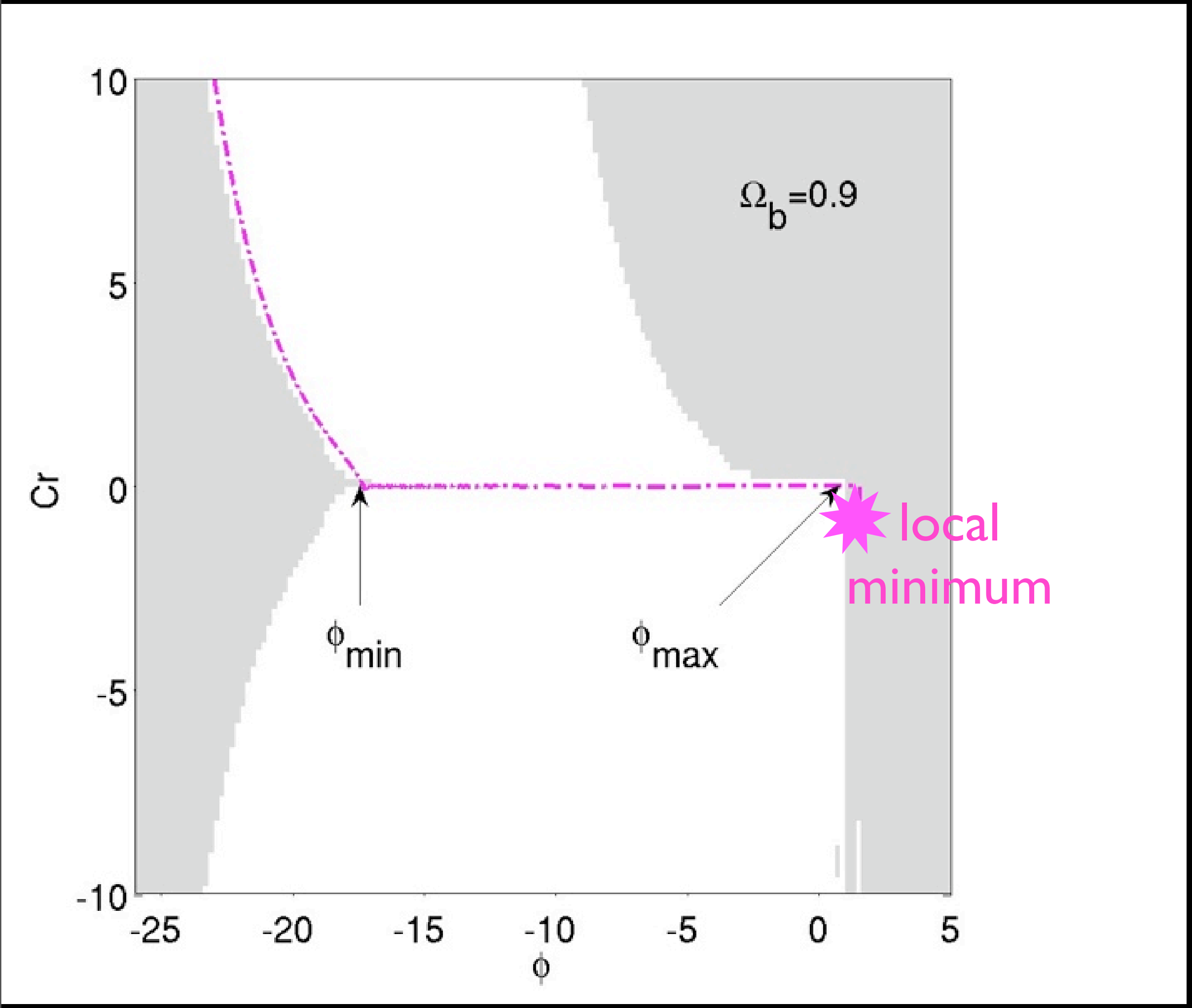

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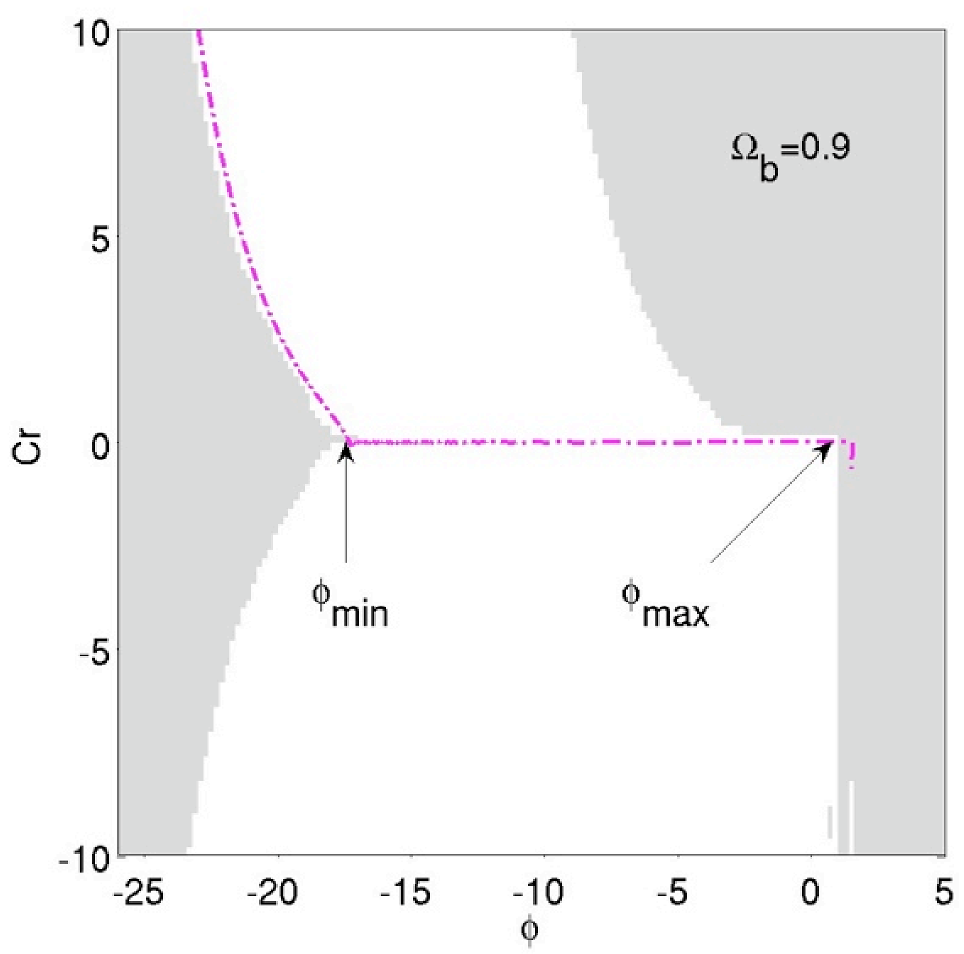
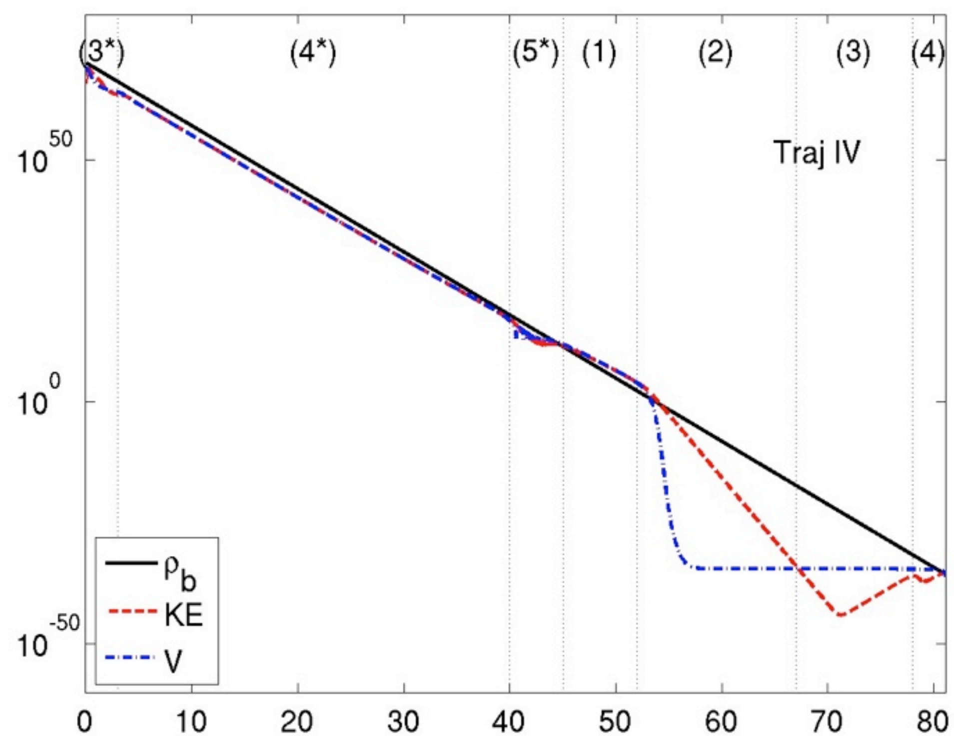


1. Potential dom.
2. Kination
3. Freeze out
4. Scaling
5. Oscillation



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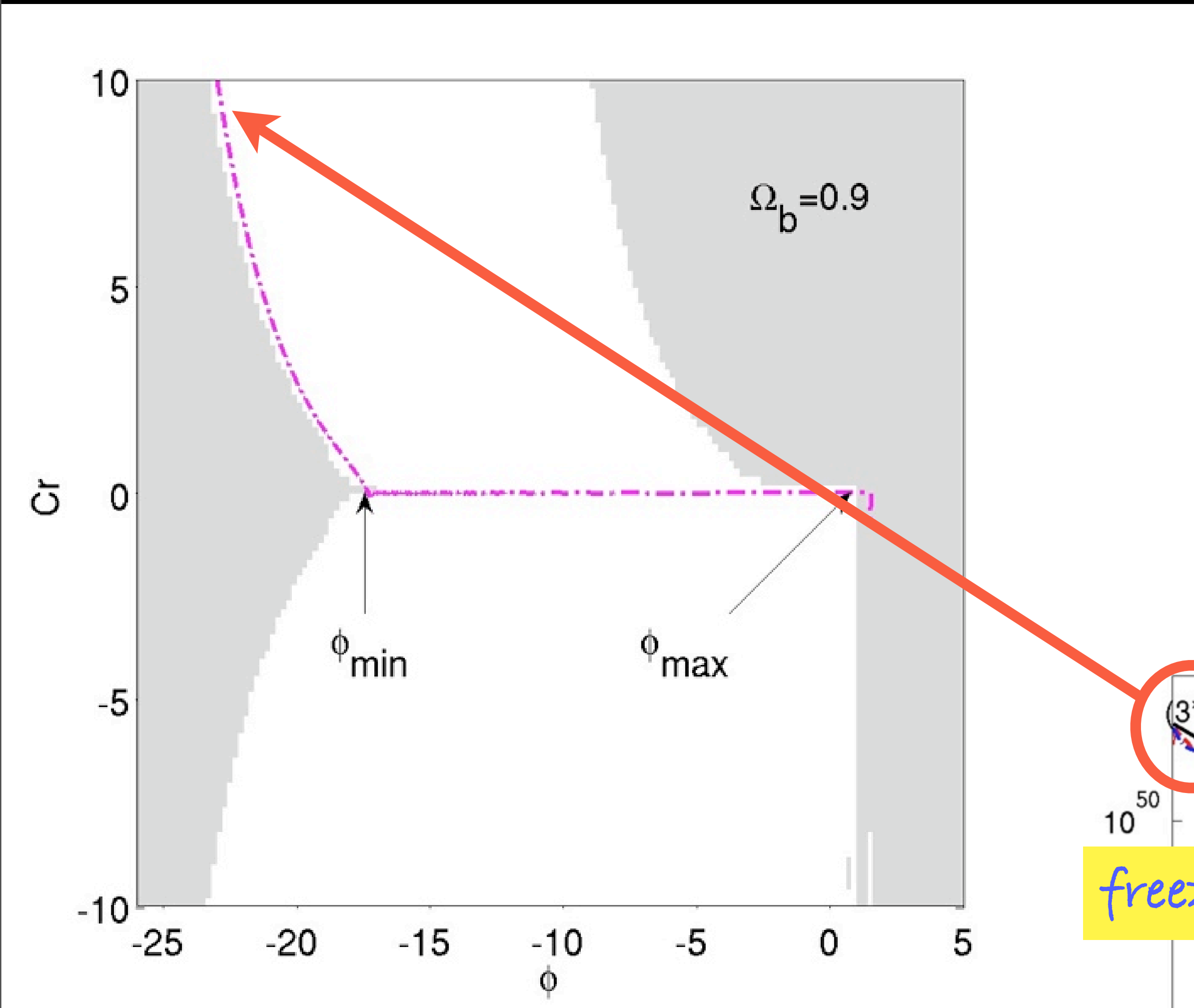

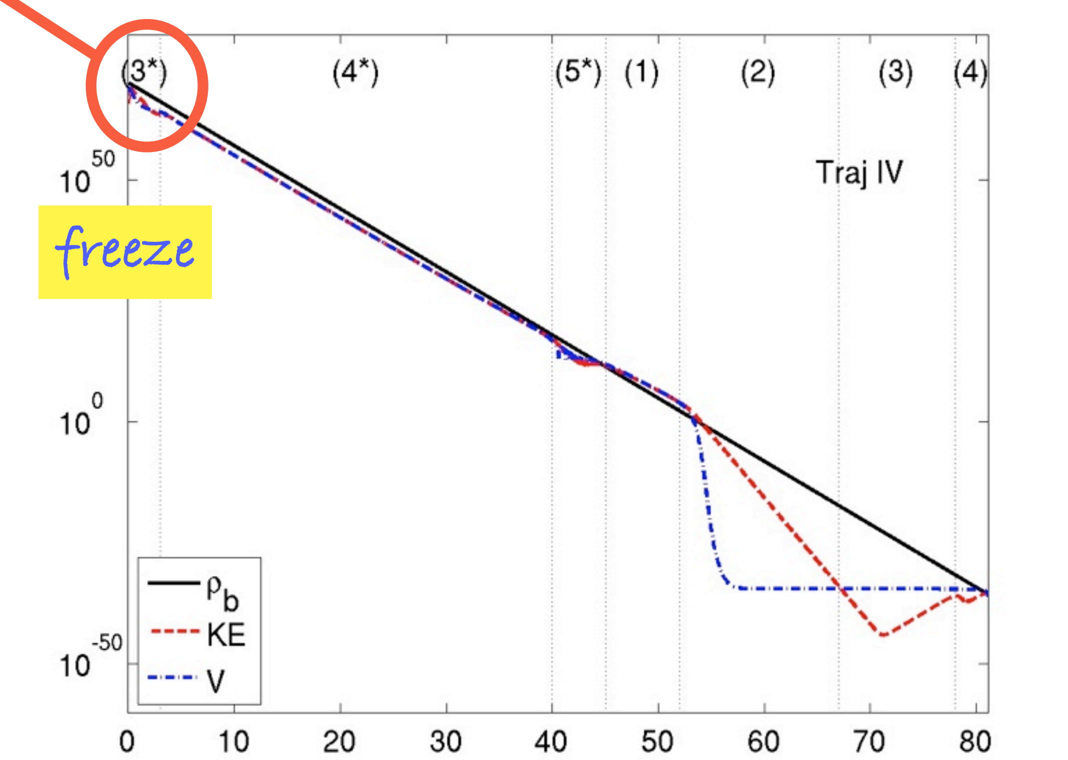

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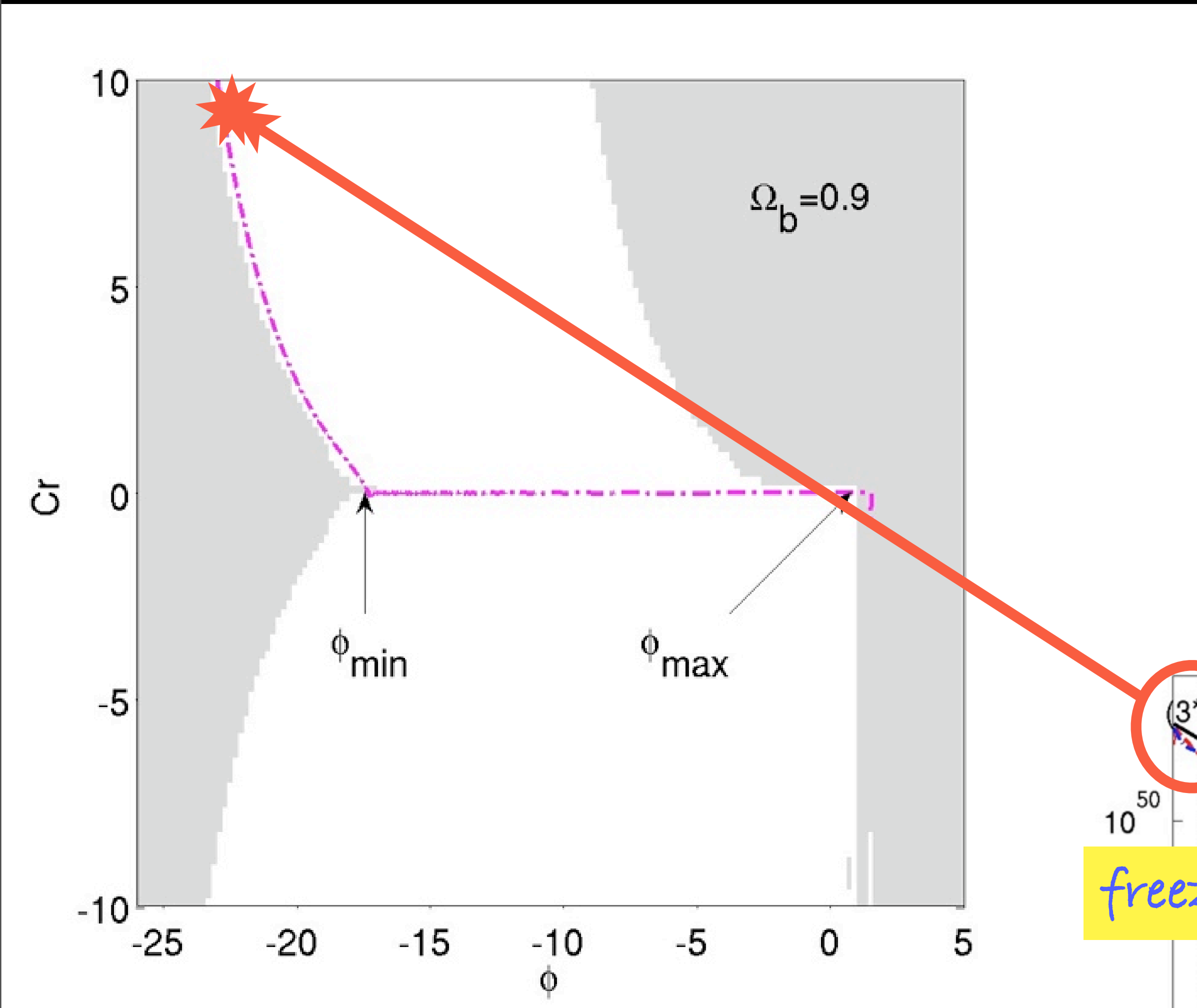

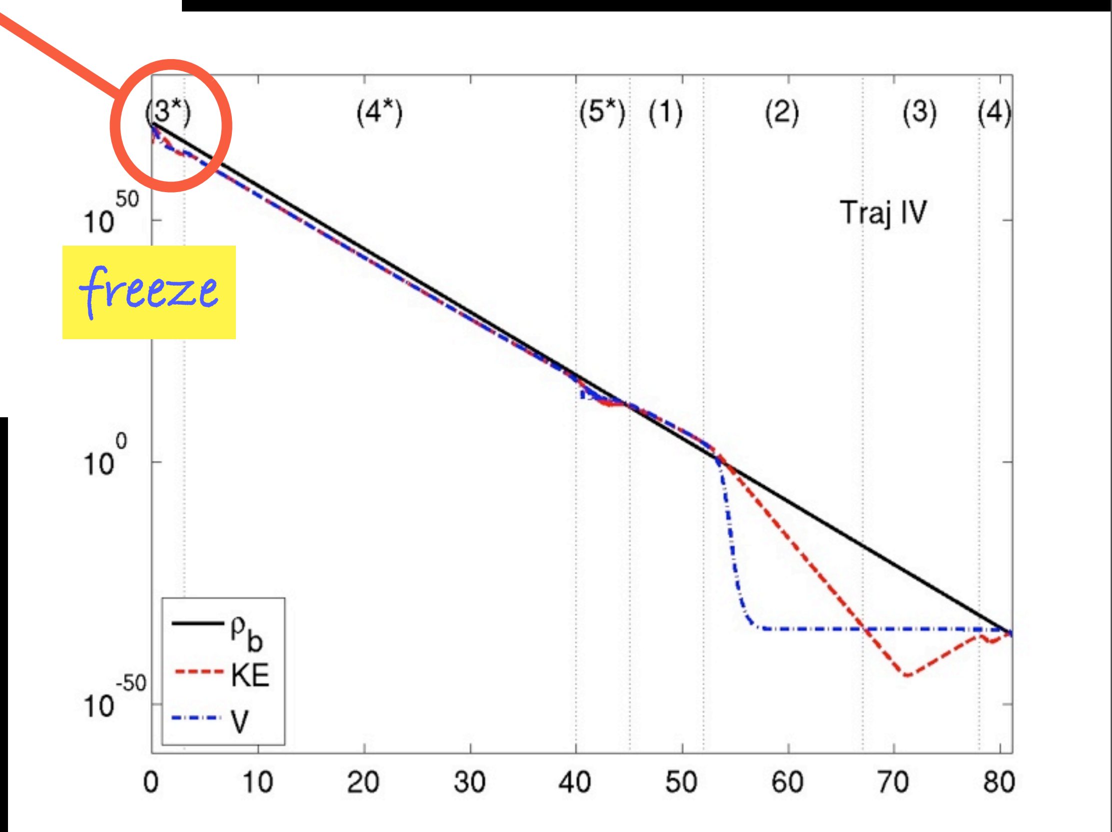

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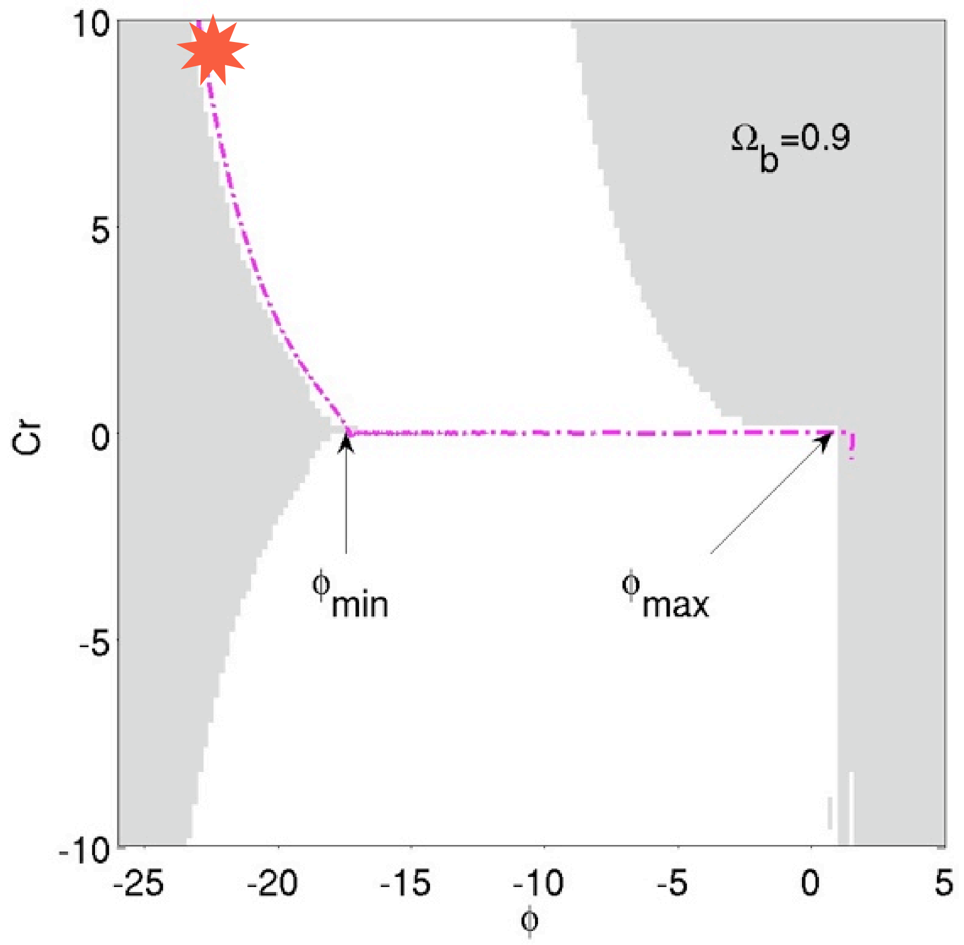

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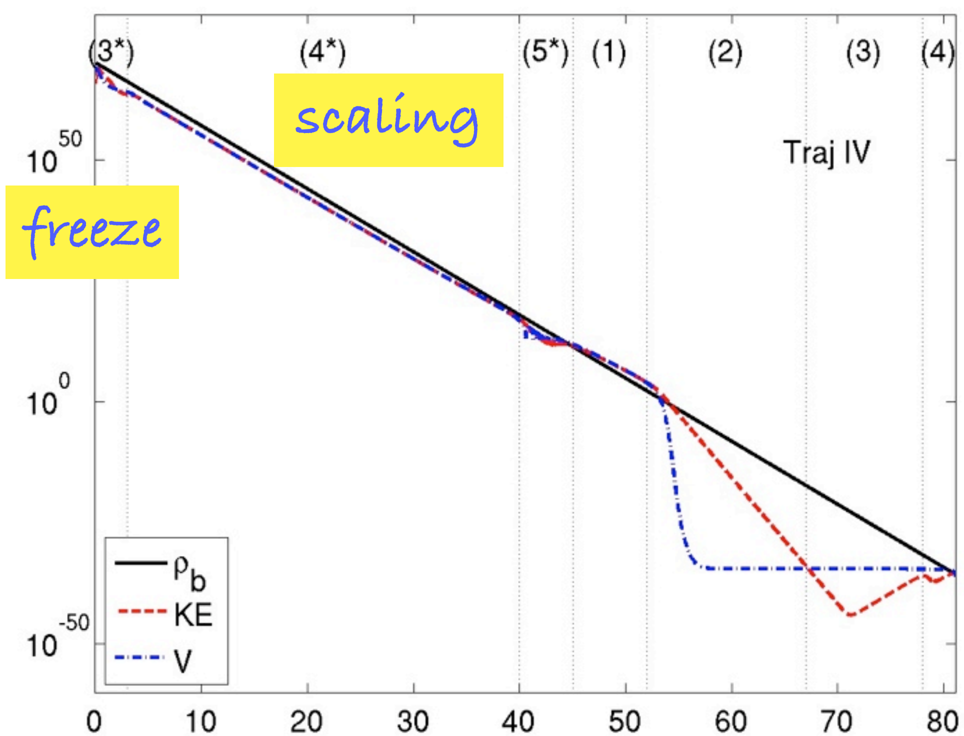

scaling condition:

$3\gamma < \lambda^2 + \delta^2/2$

$$\lambda \equiv -\frac{1}{V}\frac{\partial V}{\partial \phi} \qquad \delta \equiv -\frac{1}{V}\frac{\partial V}{\partial C_r}$$

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Two REAL Fields

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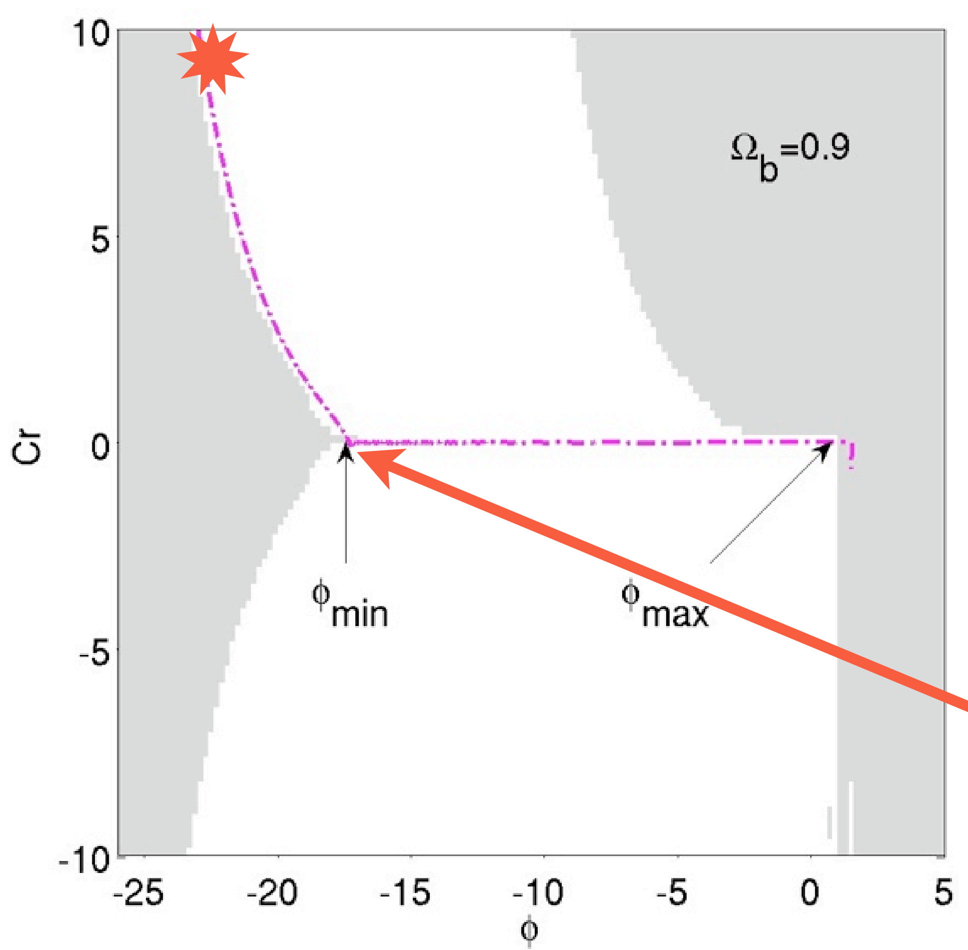

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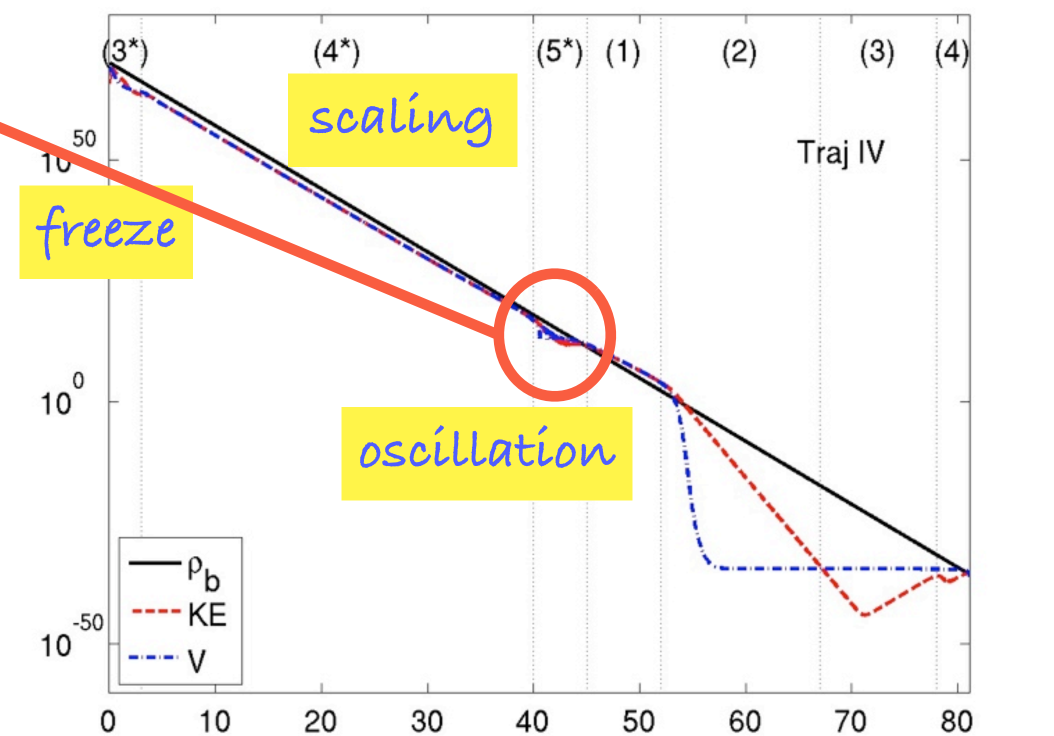

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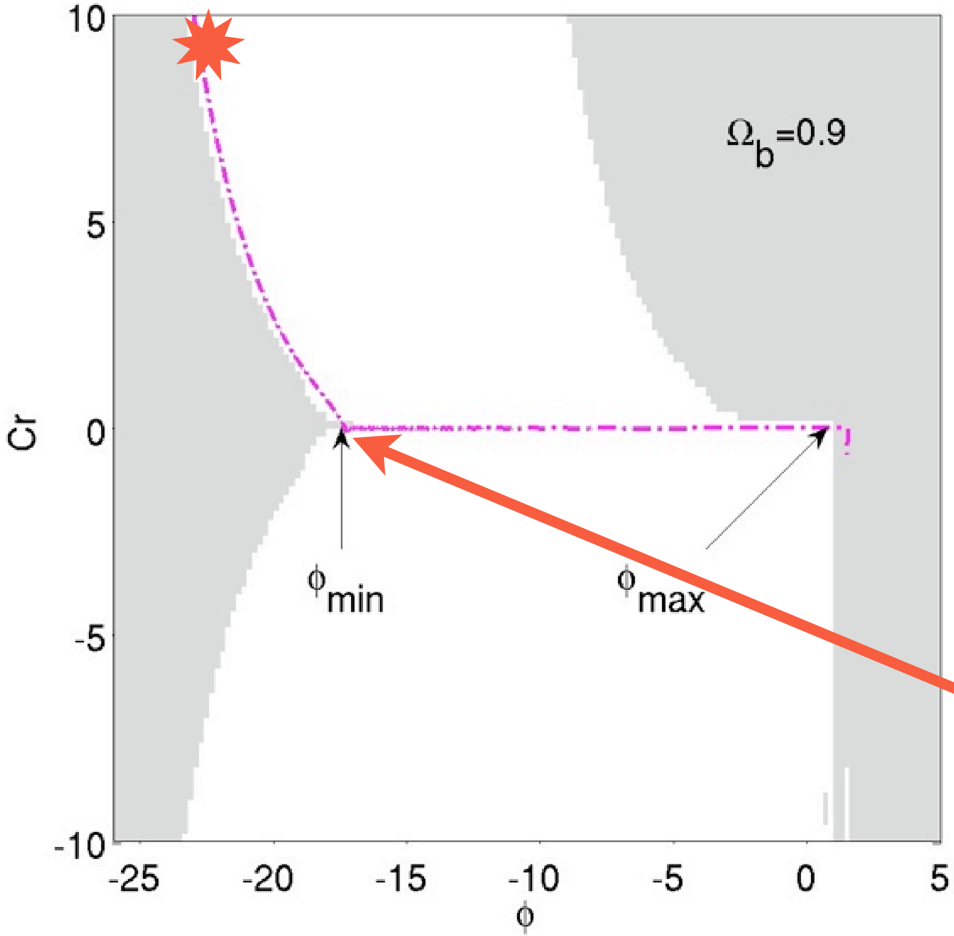

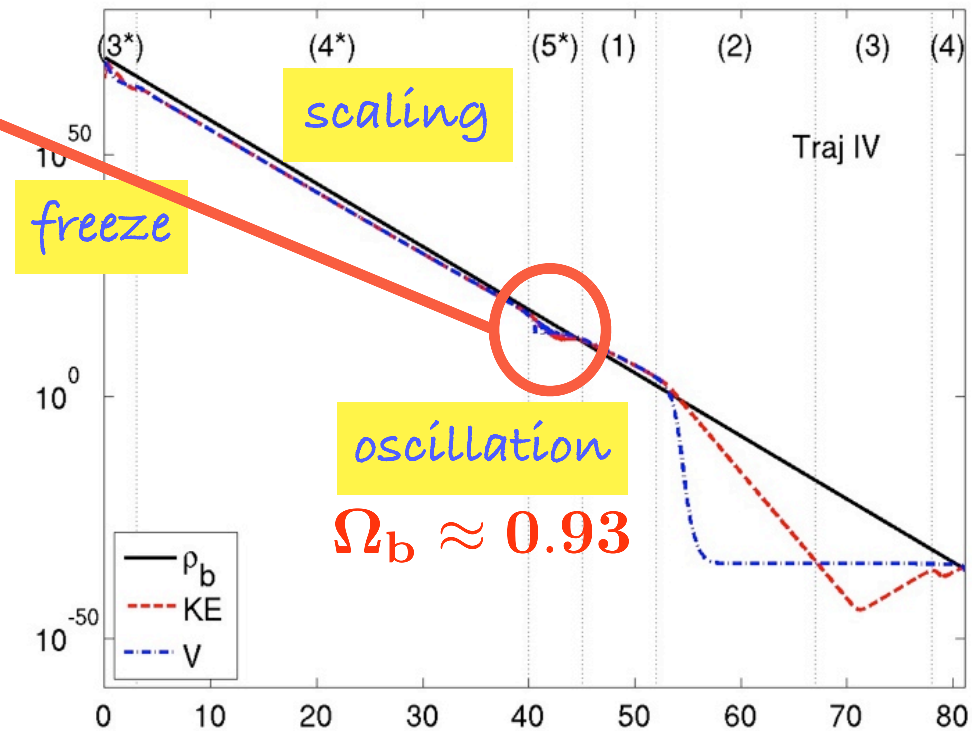

$\Omega_b \approx 0.93$

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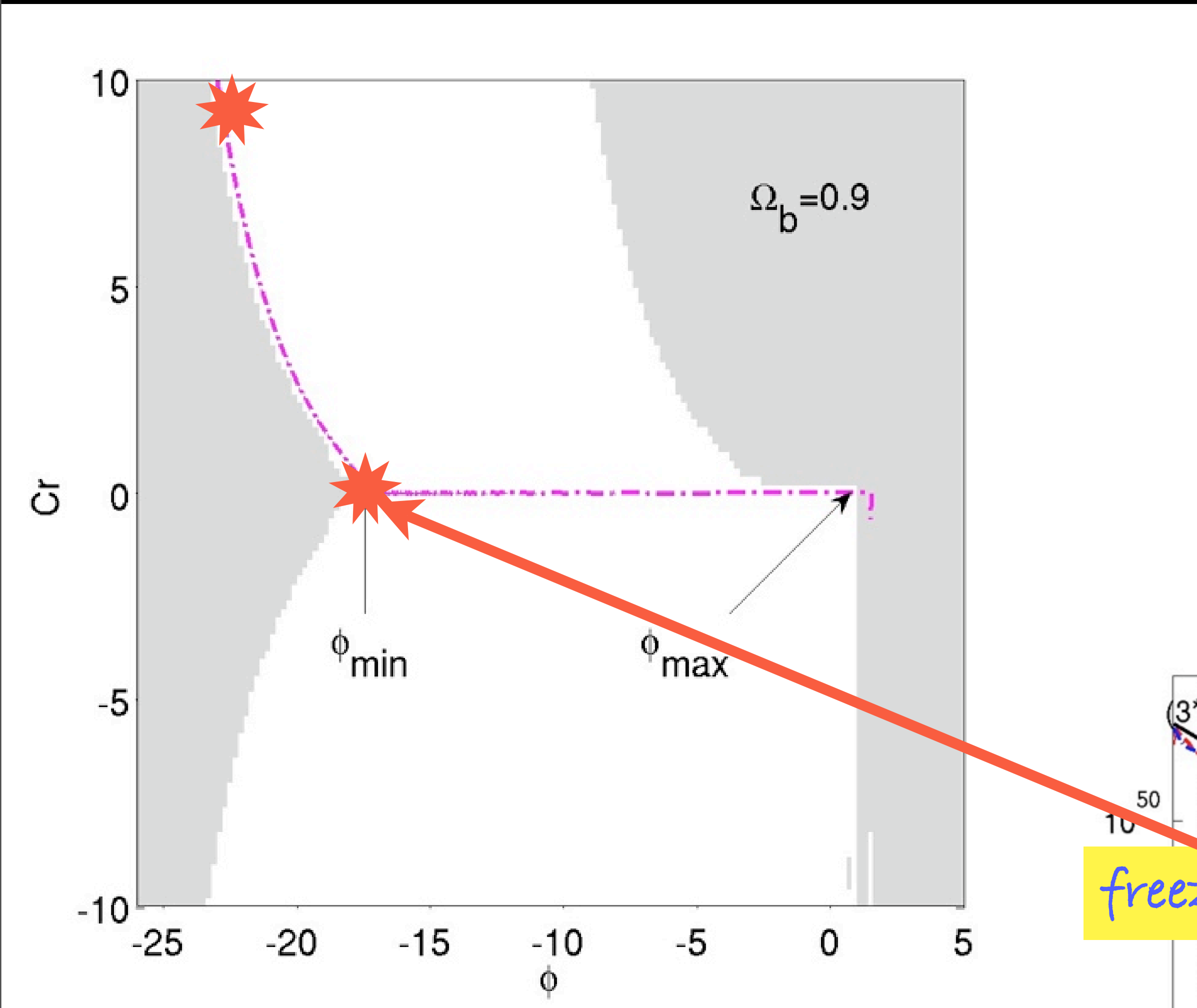

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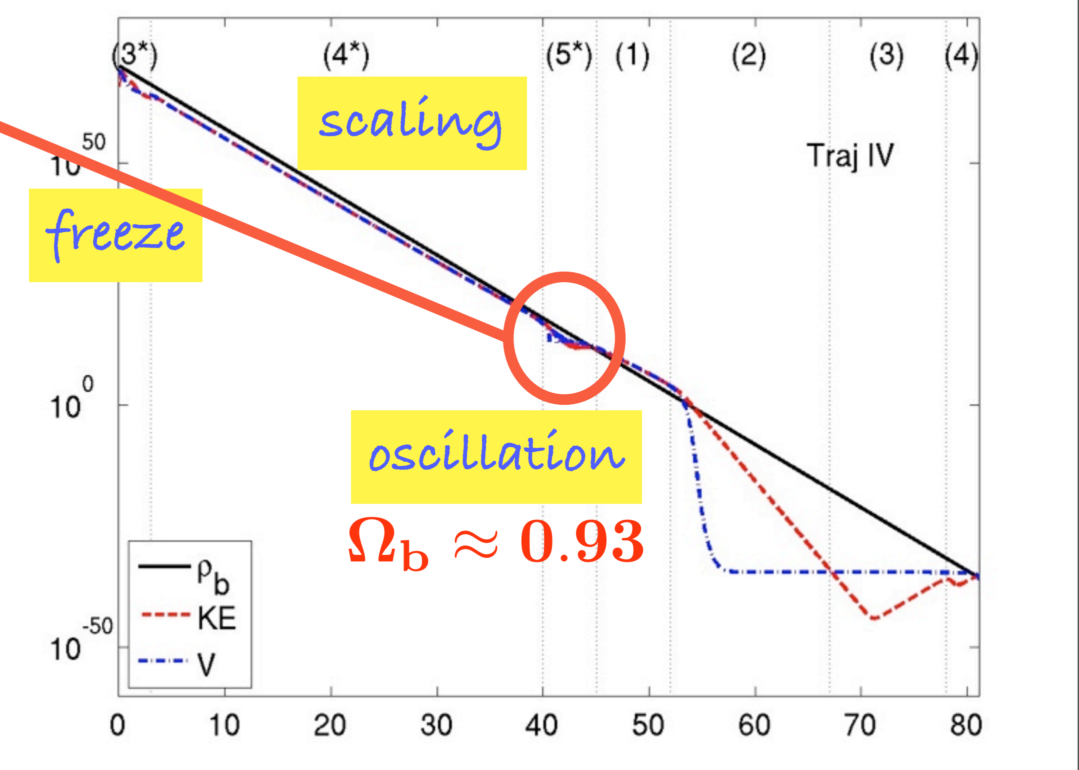

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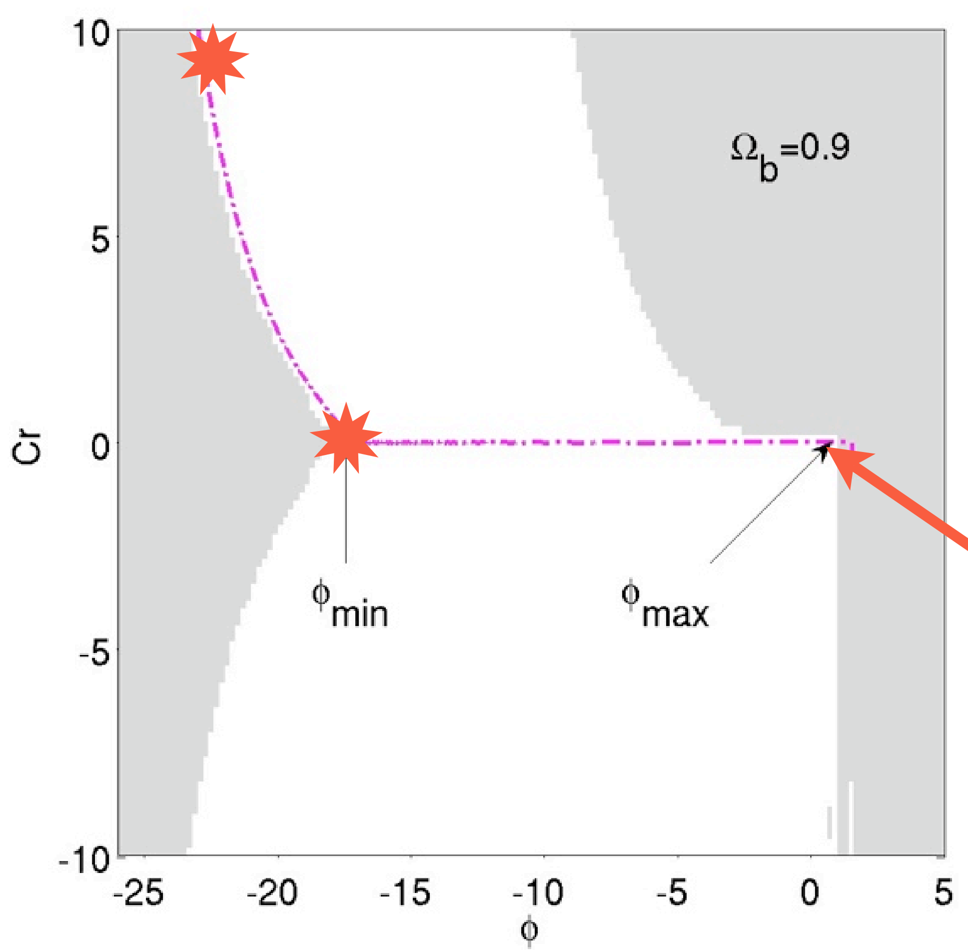

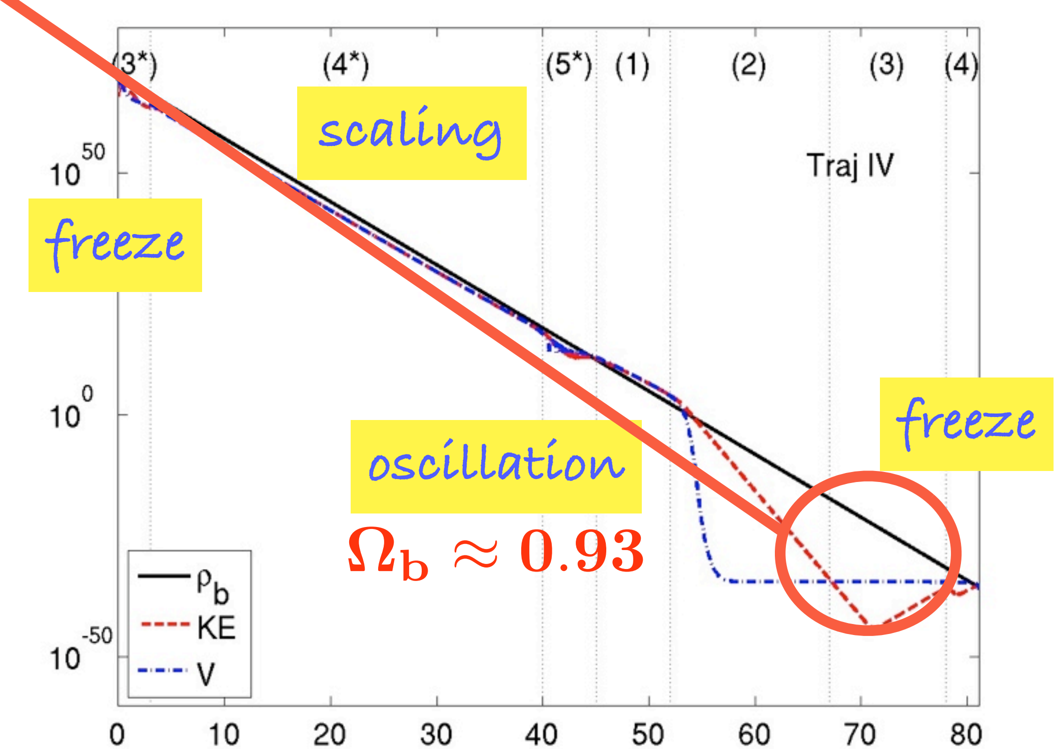

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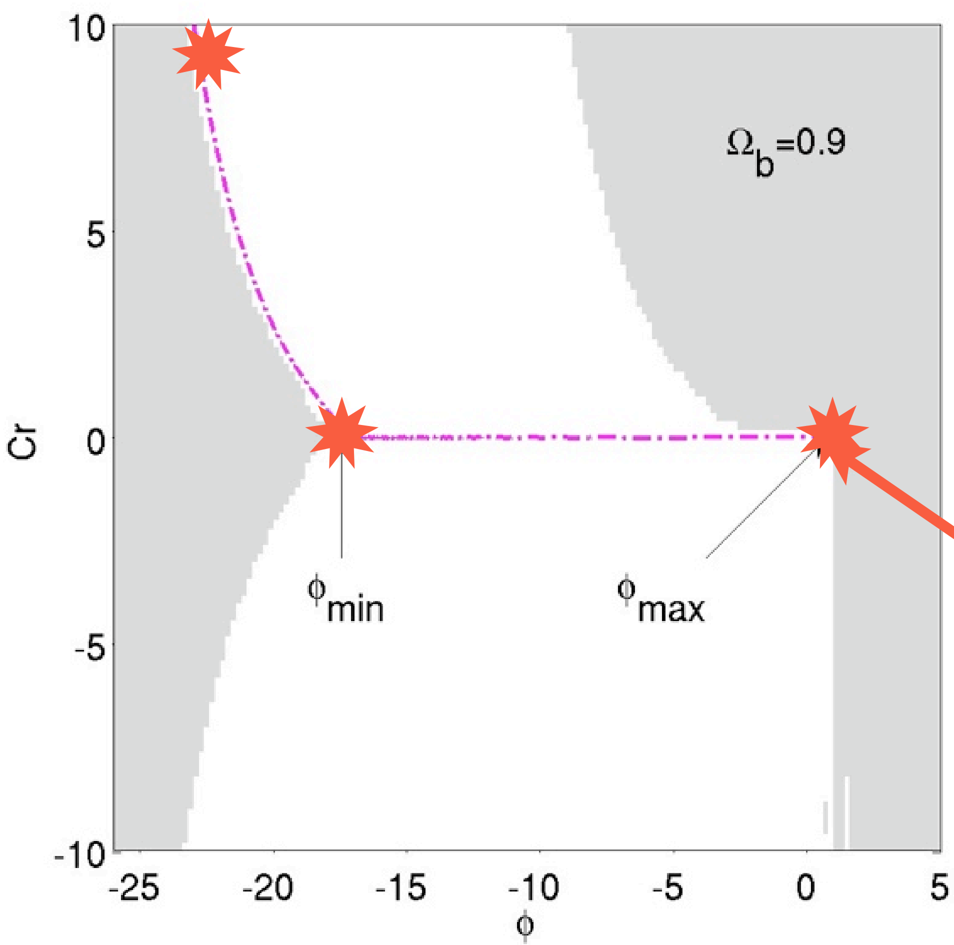

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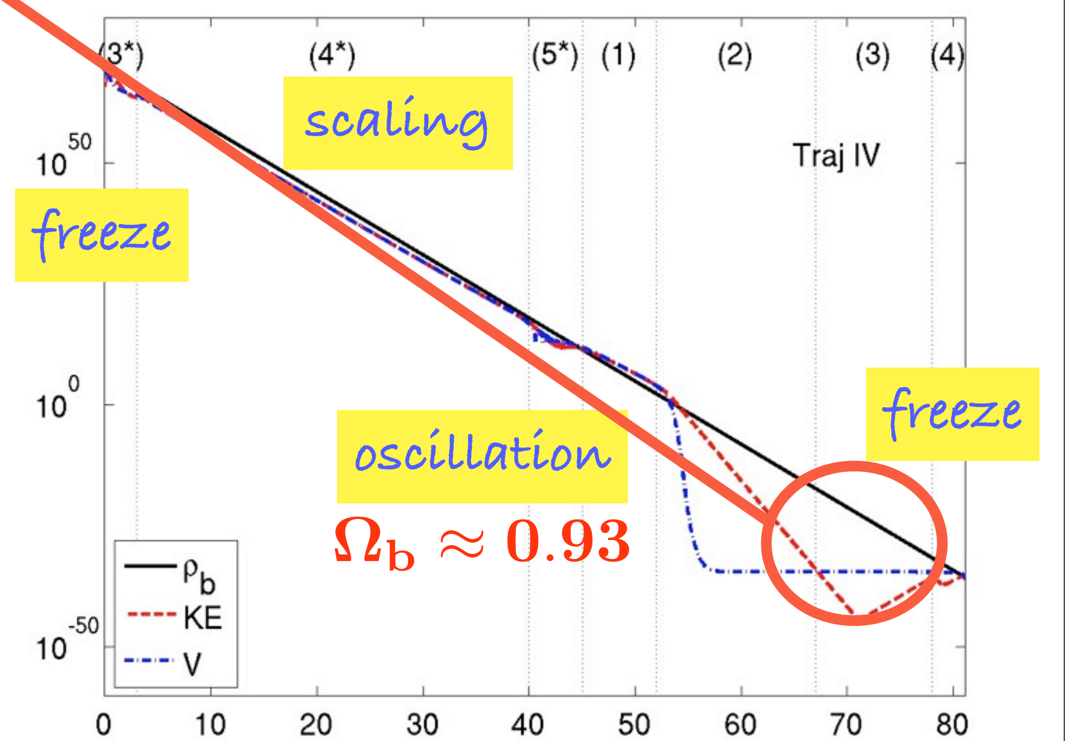
4. Scaling
5. Oscillation



scaling condition:

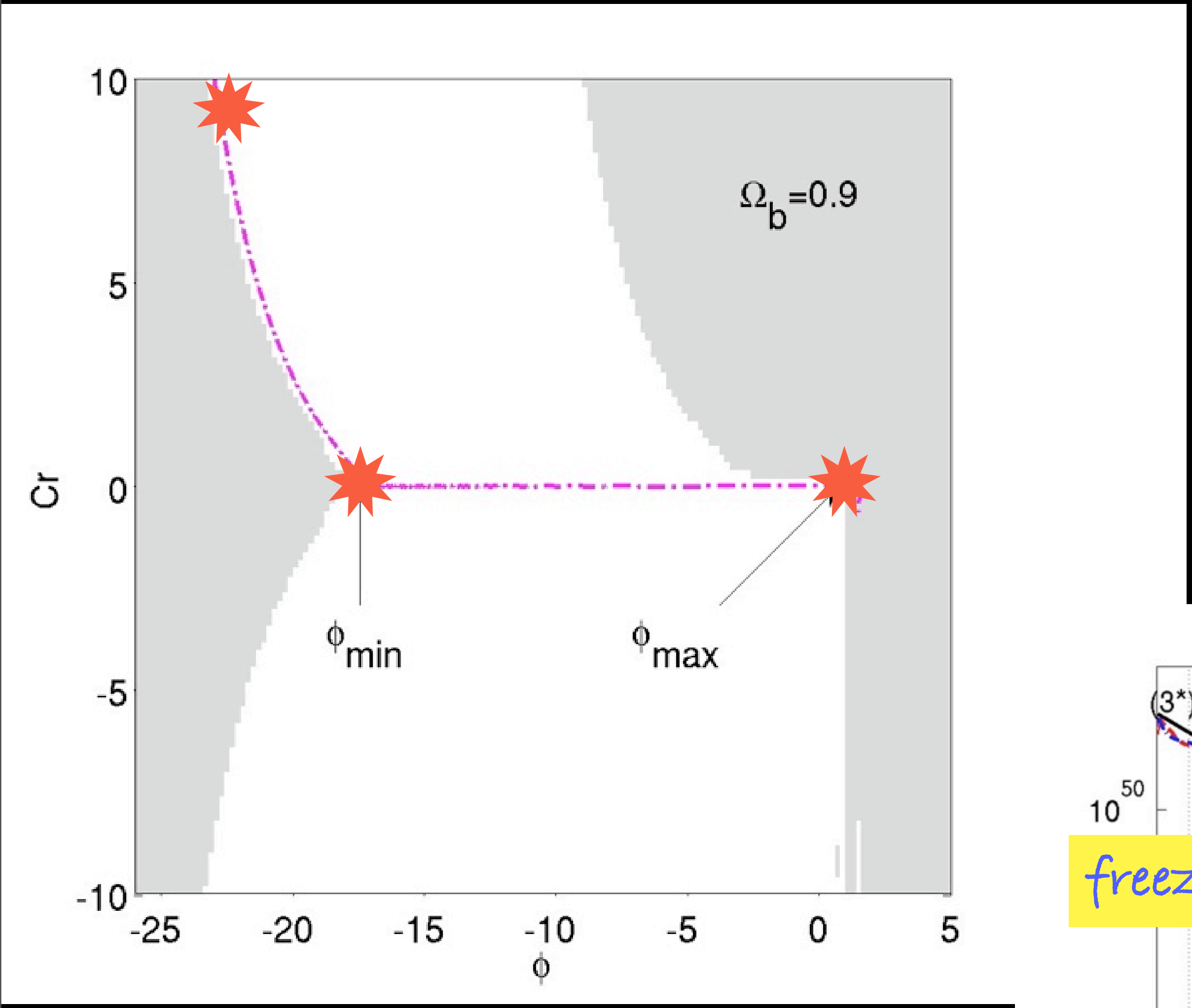
$3\gamma < \lambda^2 + \delta^2/2$

$$\lambda \equiv -\frac{1}{V}\frac{\partial V}{\partial \phi} \qquad \delta \equiv -\frac{1}{V}\frac{\partial V}{\partial C_r}$$

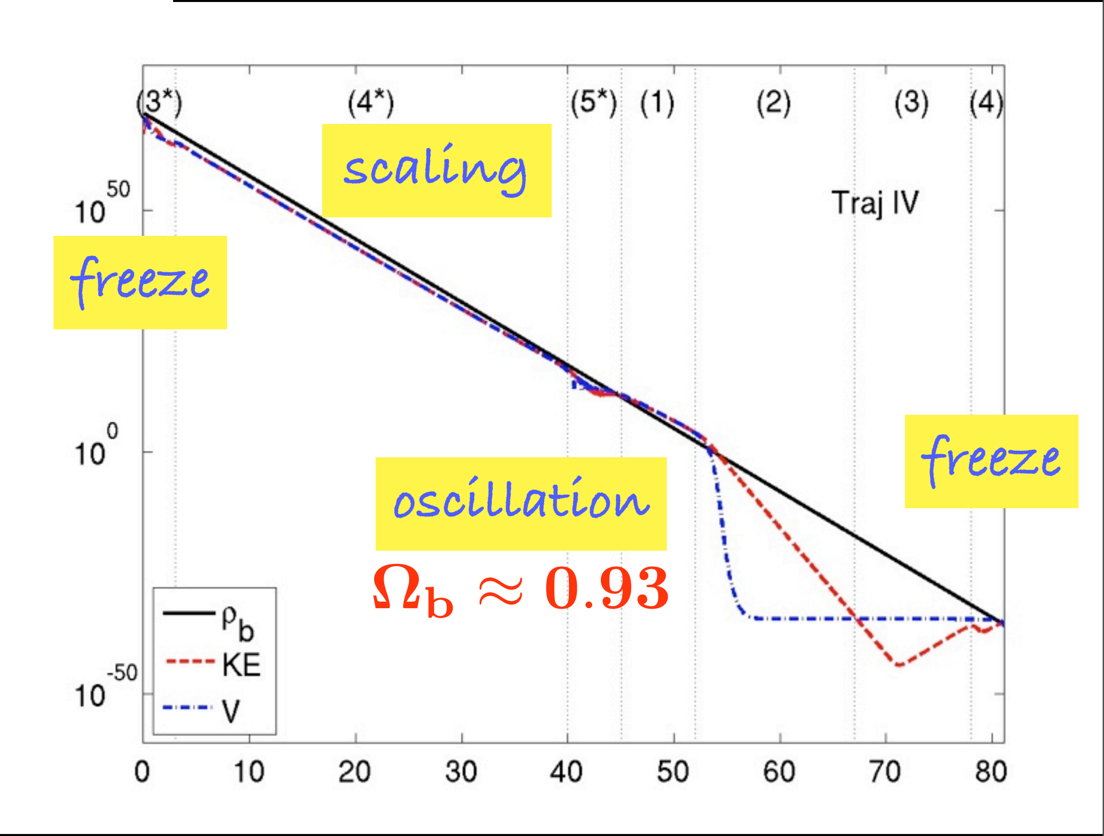
$C_i = T_i = 0$

Two REAL Fields

$\Omega_b = 0.9$



1. Potential dom.
2. Kination
3. Freeze out
4. Scaling
5. Oscillation



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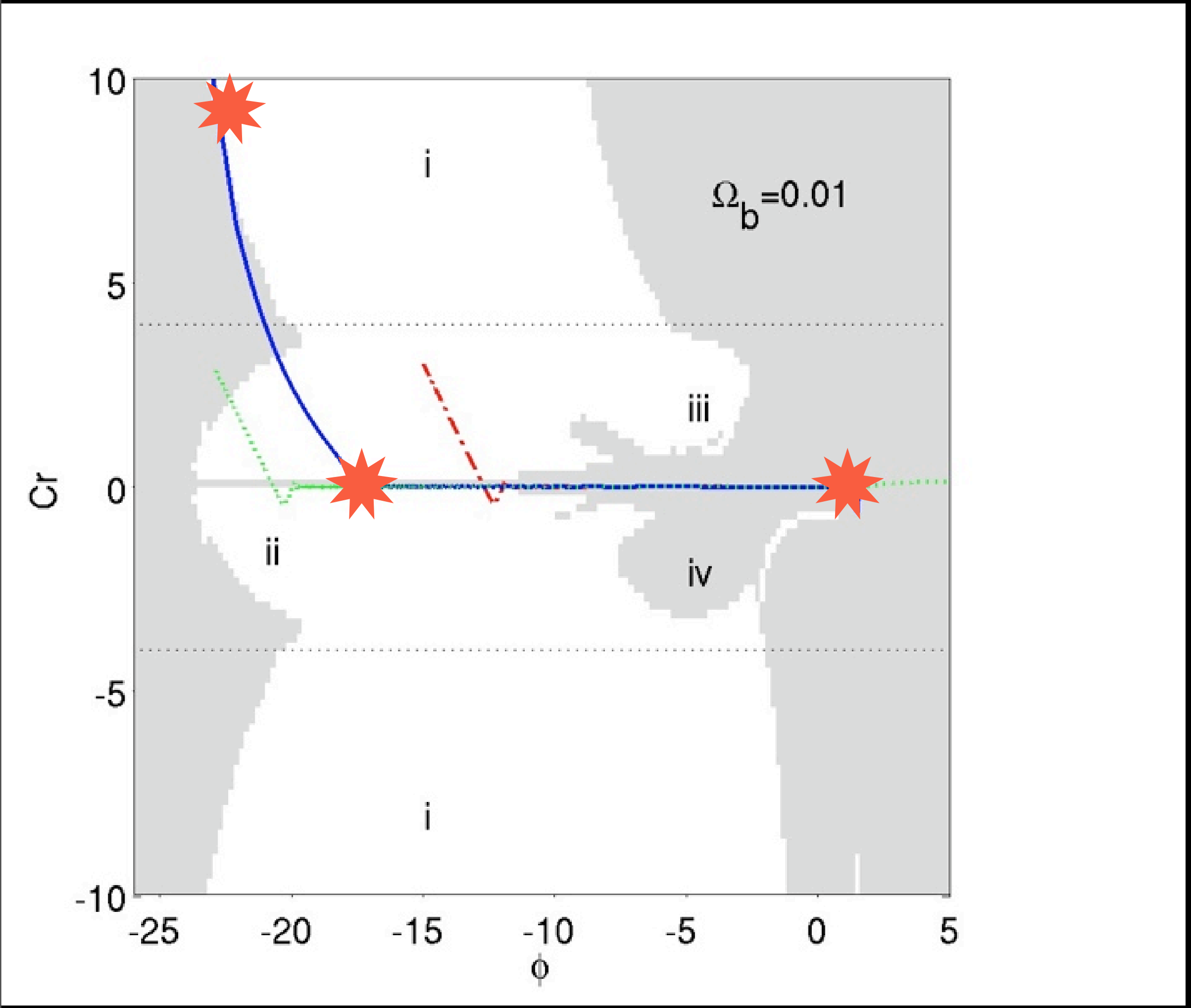
$C_i = T_i = 0$

Two REAL Fields

$\Omega_b = 0.01$



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5. Oscillation

$C_i = T_i = 0$

Two REAL Fields

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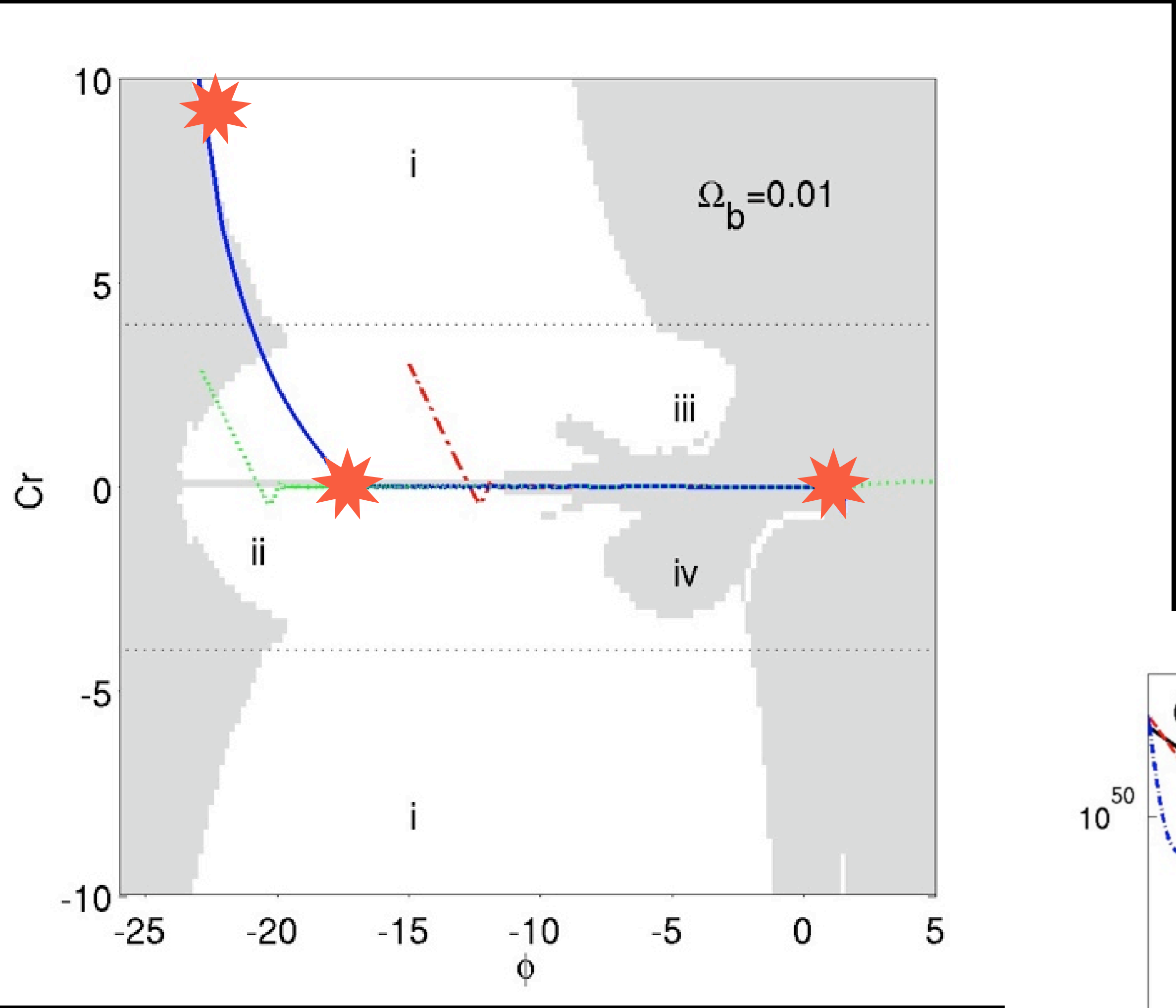
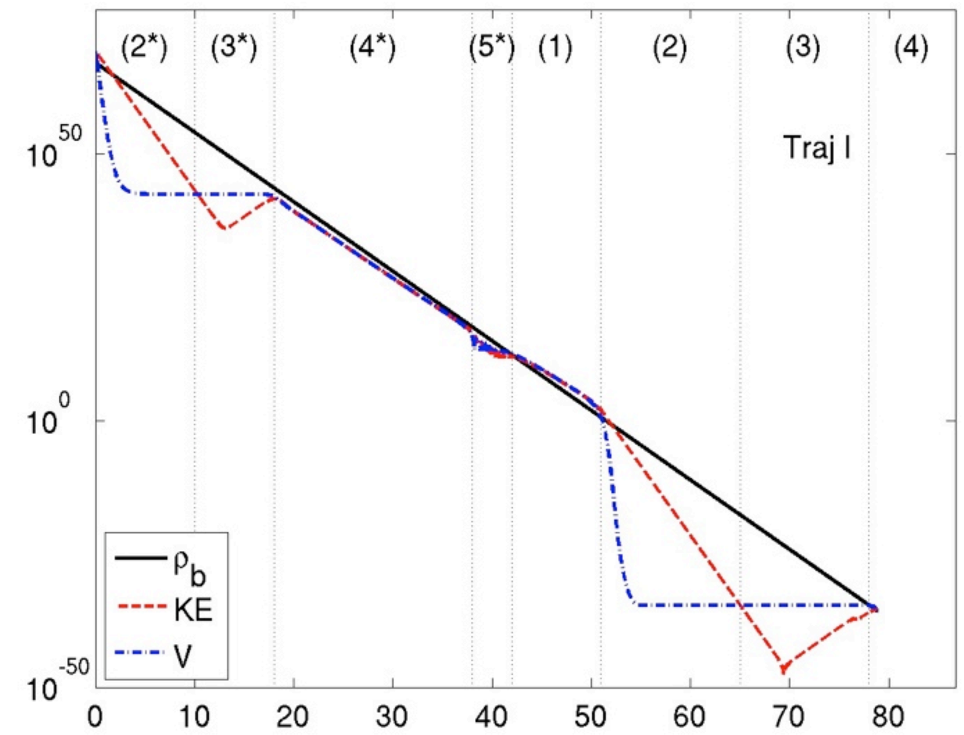


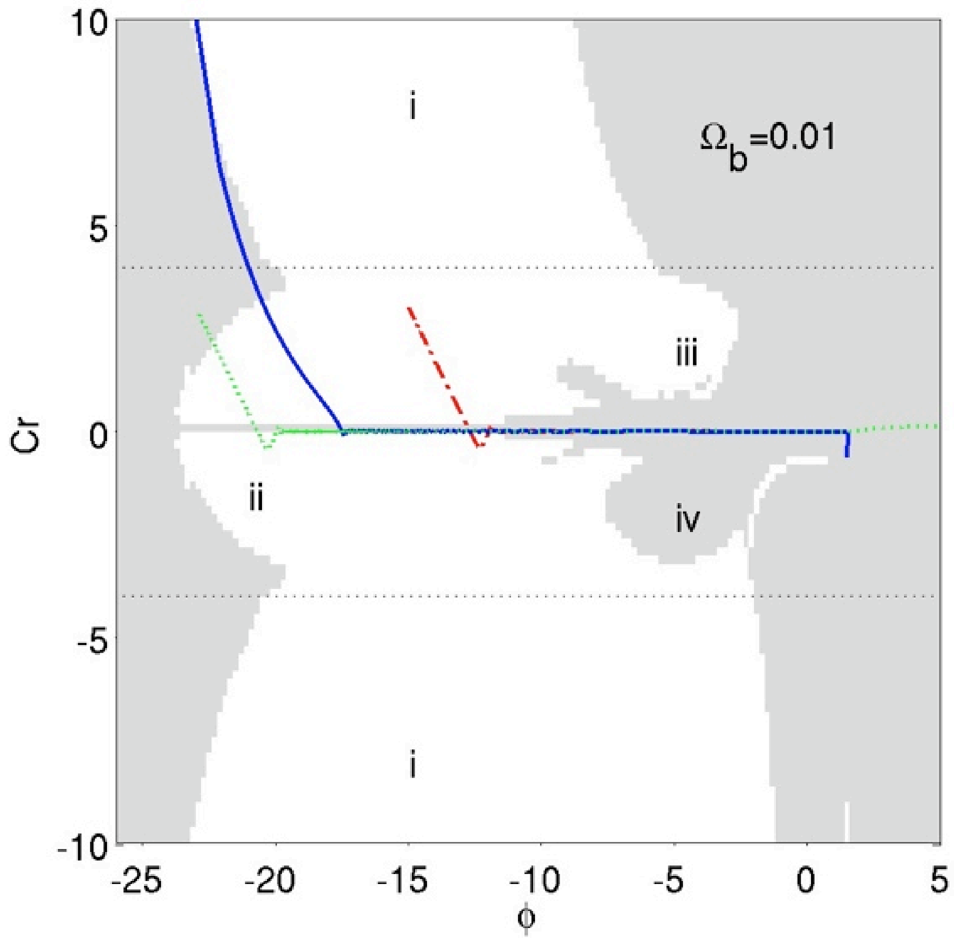
1. Potential dom.
2. Kination
3. Freeze out
4. Scaling
5. Oscillation



$C_i = T_i = 0$

Two REAL Fields

$\Omega_b = 0.01$



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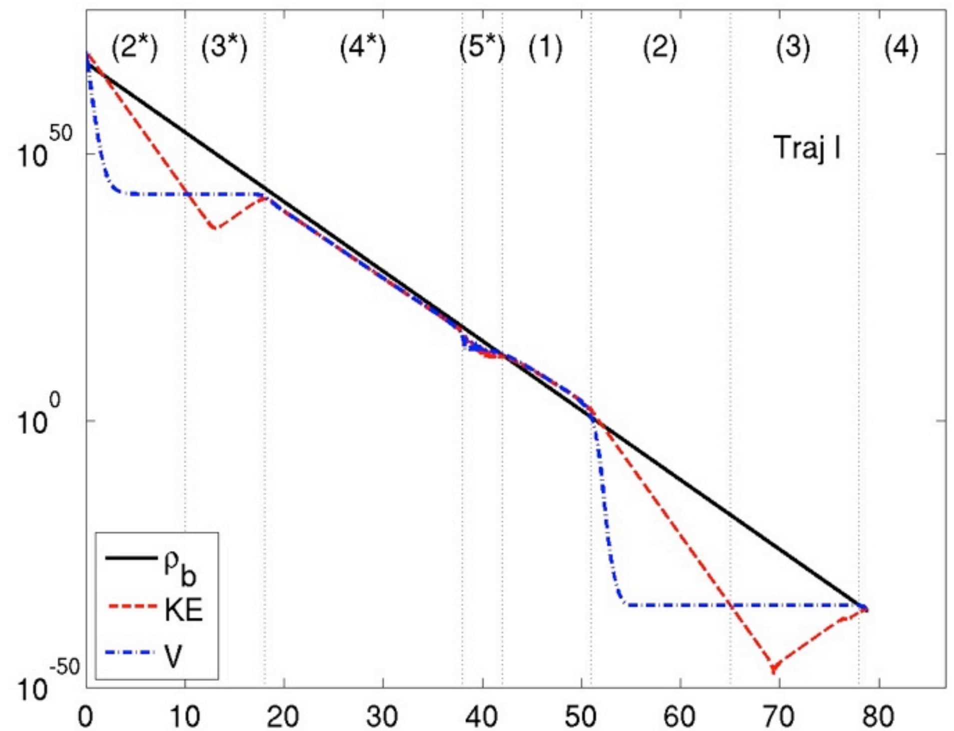
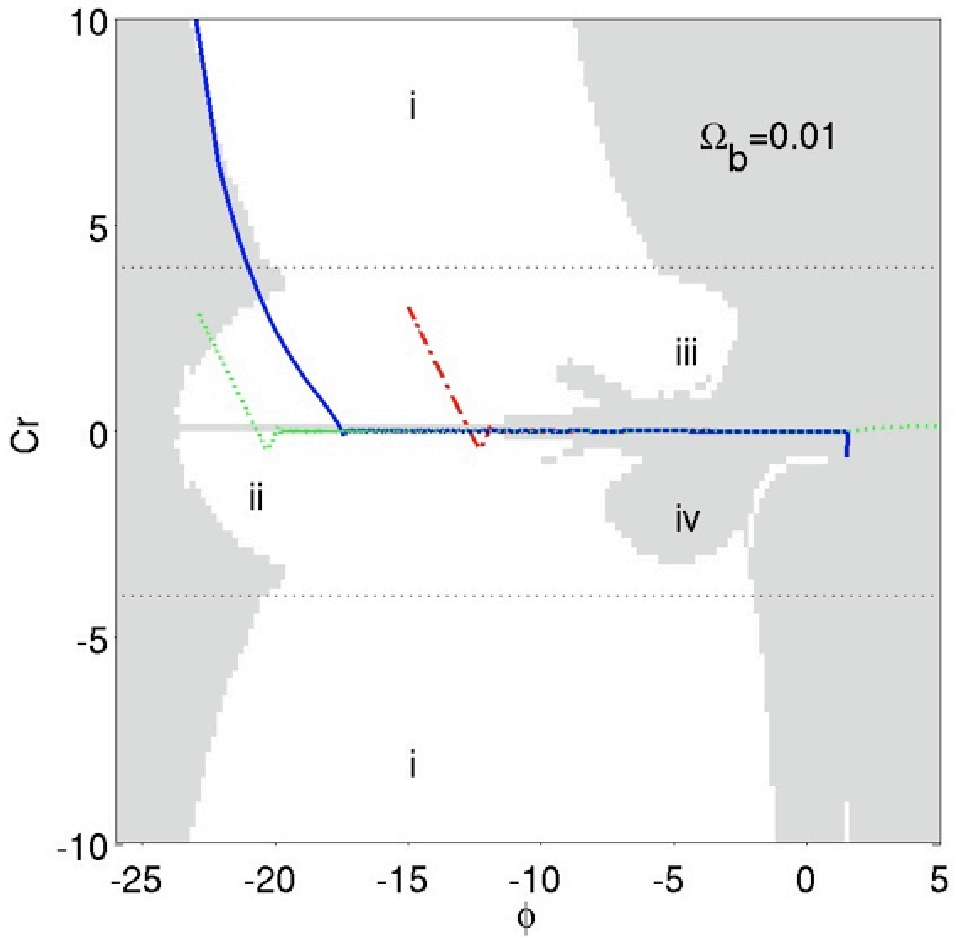
2. Kination
3. Freeze out
4. Scaling
5. Oscillation



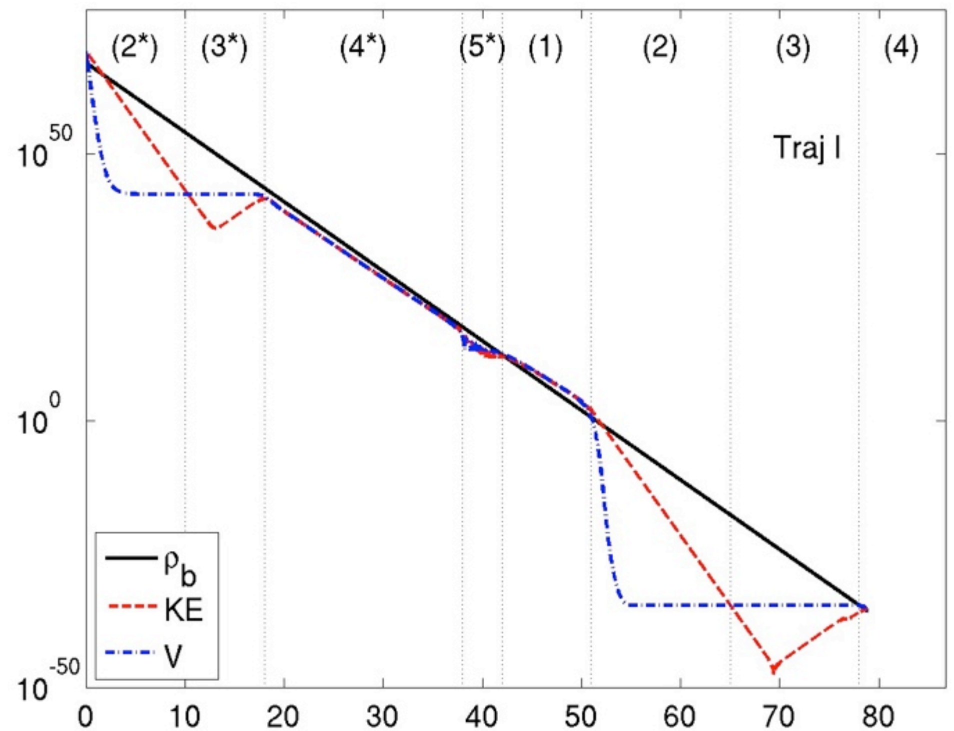
$C_i = T_i = 0$

Two REAL Fields

$\Omega_b = 0.01$



1. Potential dom.
2. Kination
3. Freeze out
4. Scaling
5. Oscillation



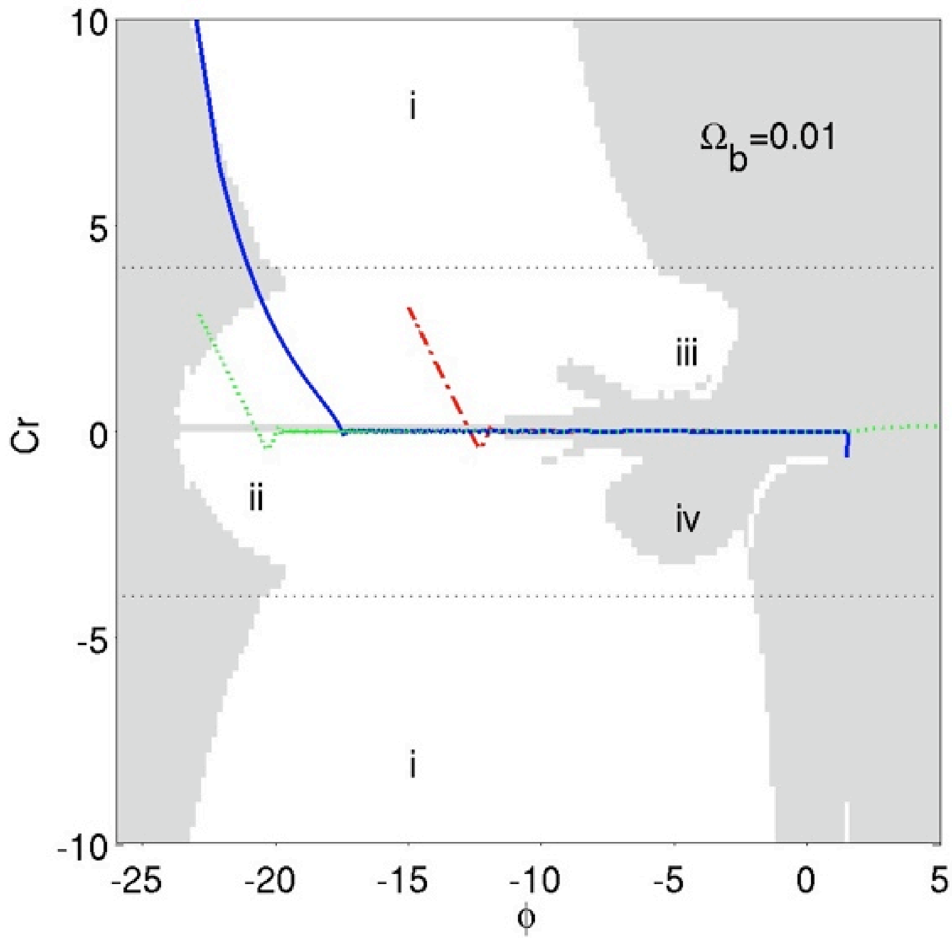
At end of scaling (oscillation):

$\Omega_b \approx 0.93$

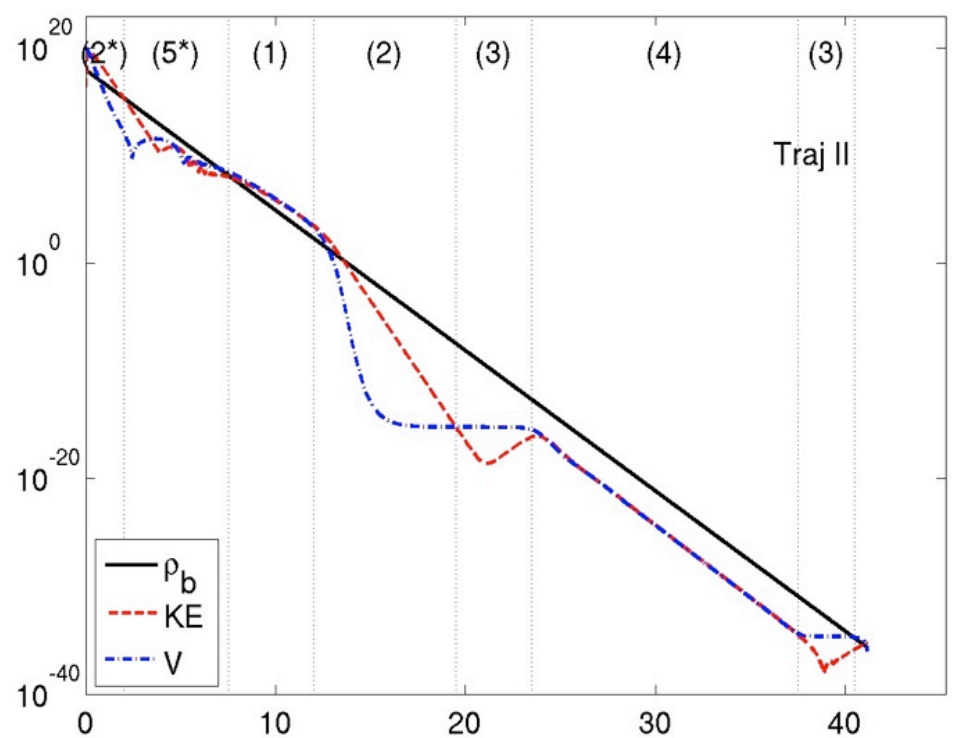
$C_i = T_i = 0$

Two REAL Fields

$\Omega_b = 0.01$



1. Potential dom.
2. Kination
3. Freeze out
4. Scaling
5. Oscillation



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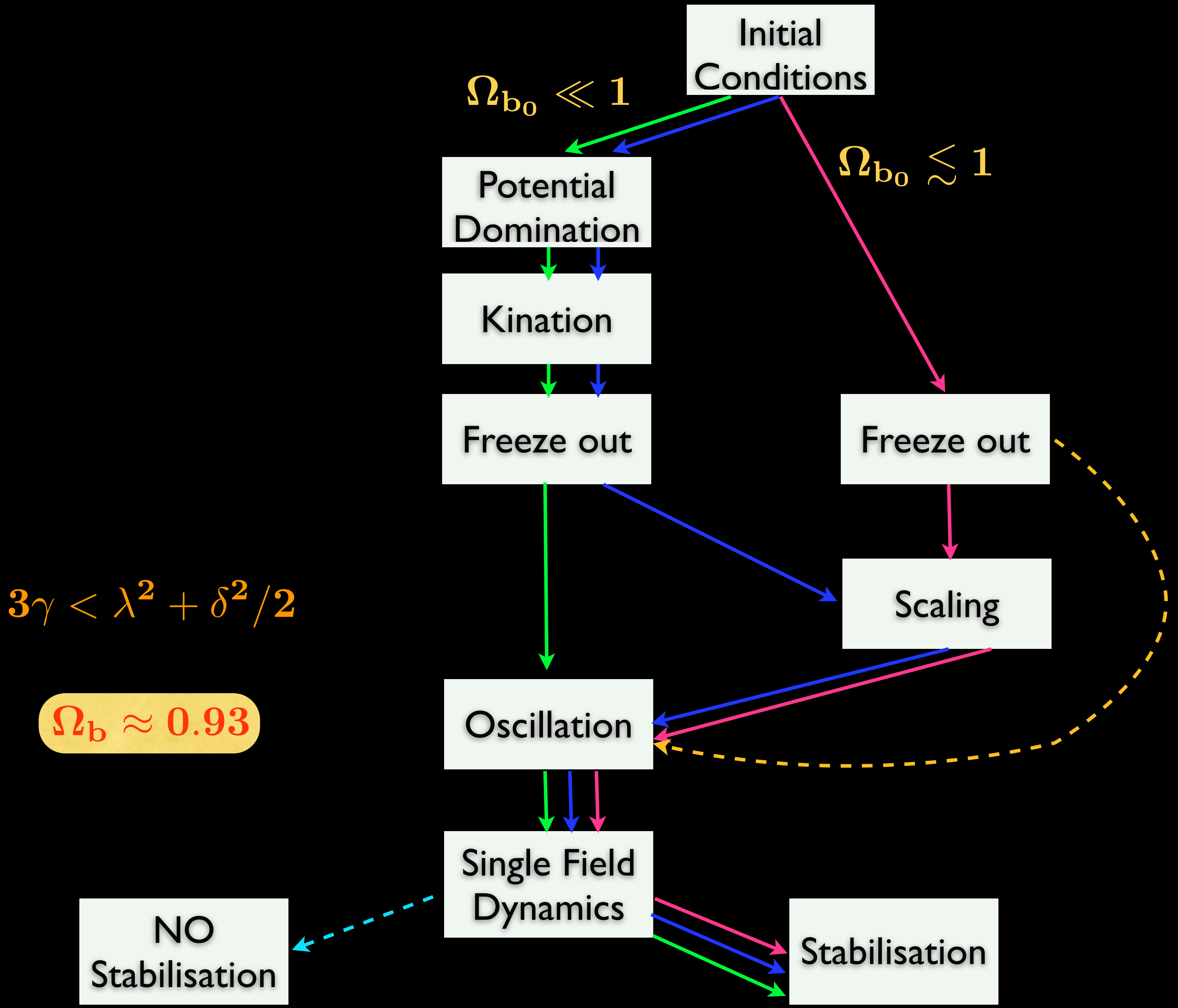
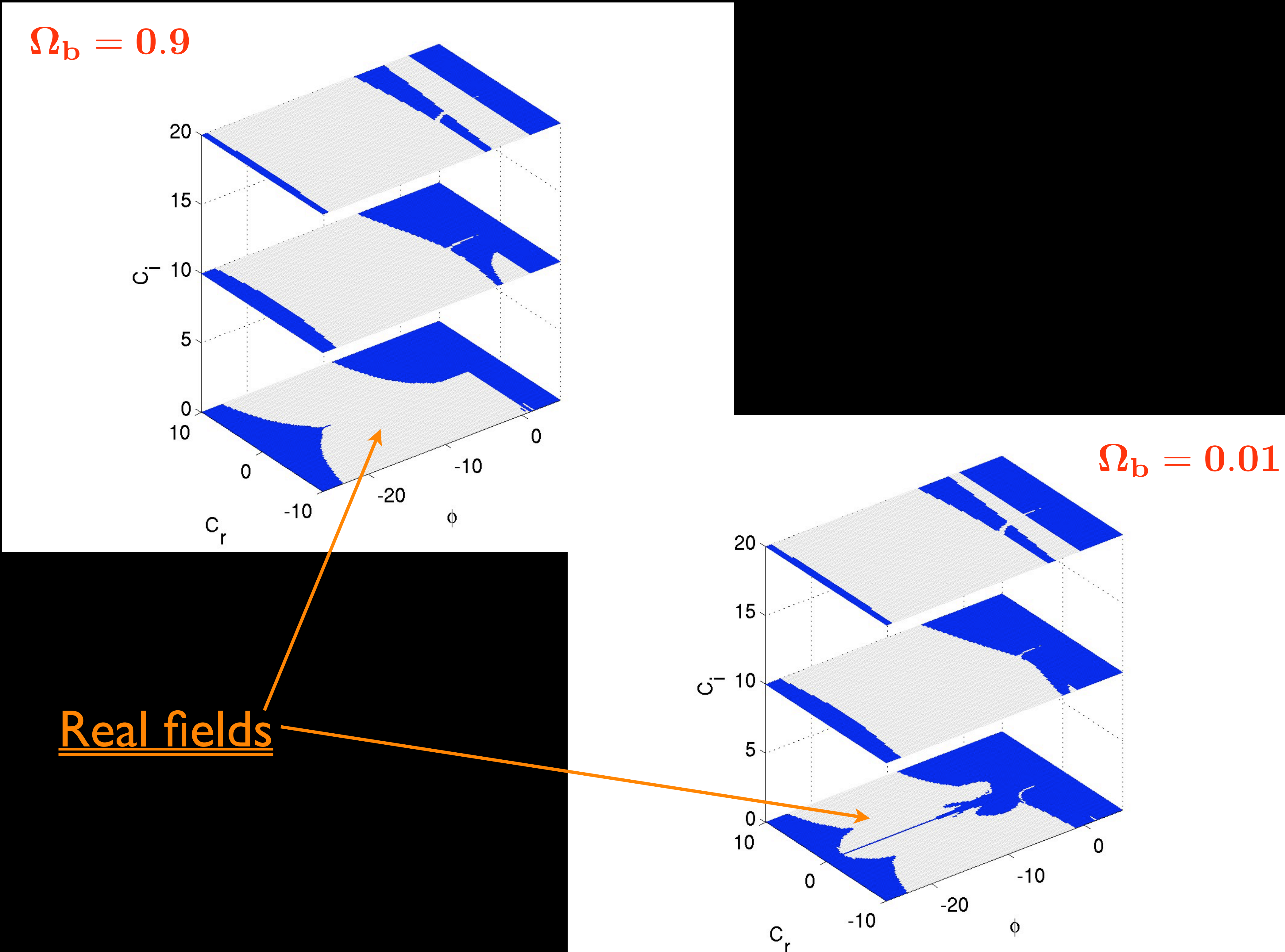
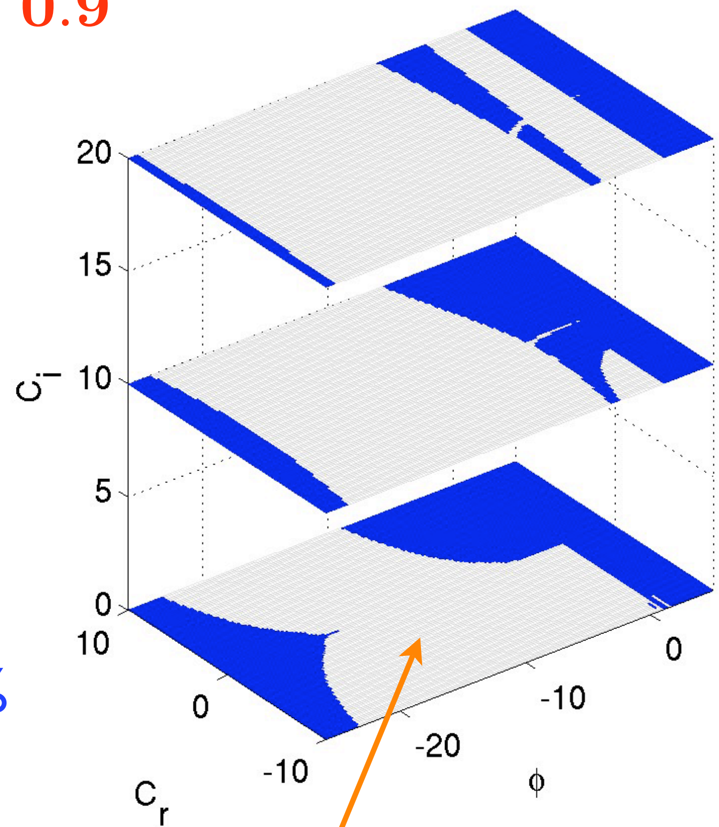

Initial Conditions
$\Omega_{b_0} \ll 1$
$\Omega_{b_0} \lesssim 1$
Potential Domination
Kination
Freeze out
Freeze out
Scaling
$3\gamma < \lambda^2 + \delta^2/2$
$\Omega_b \approx 0.93$
Oscillation
Single Field Dynamics
NO Stabilisation
Stabilisation



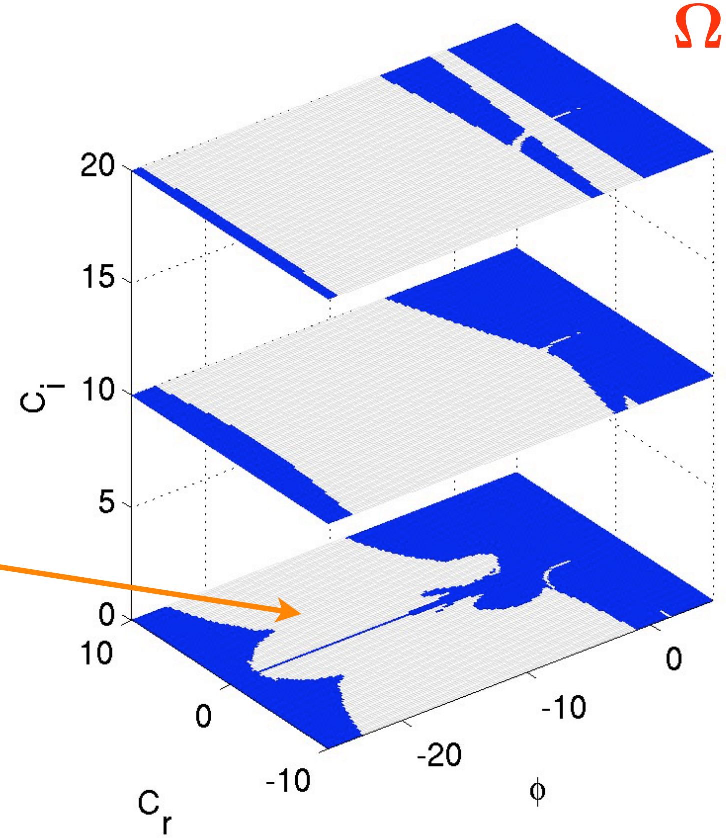
$\Omega_b = 0.9$
20
15
10
5
0
c_i
10
0
-10
c_r
-20
-10
0
ϕ
$\Omega_b = 0.01$
20
15
10
5
0
c_i
10
0
-10
c_r
-20
-10
0
ϕ
Real fields

$\Omega_b = 0.9$

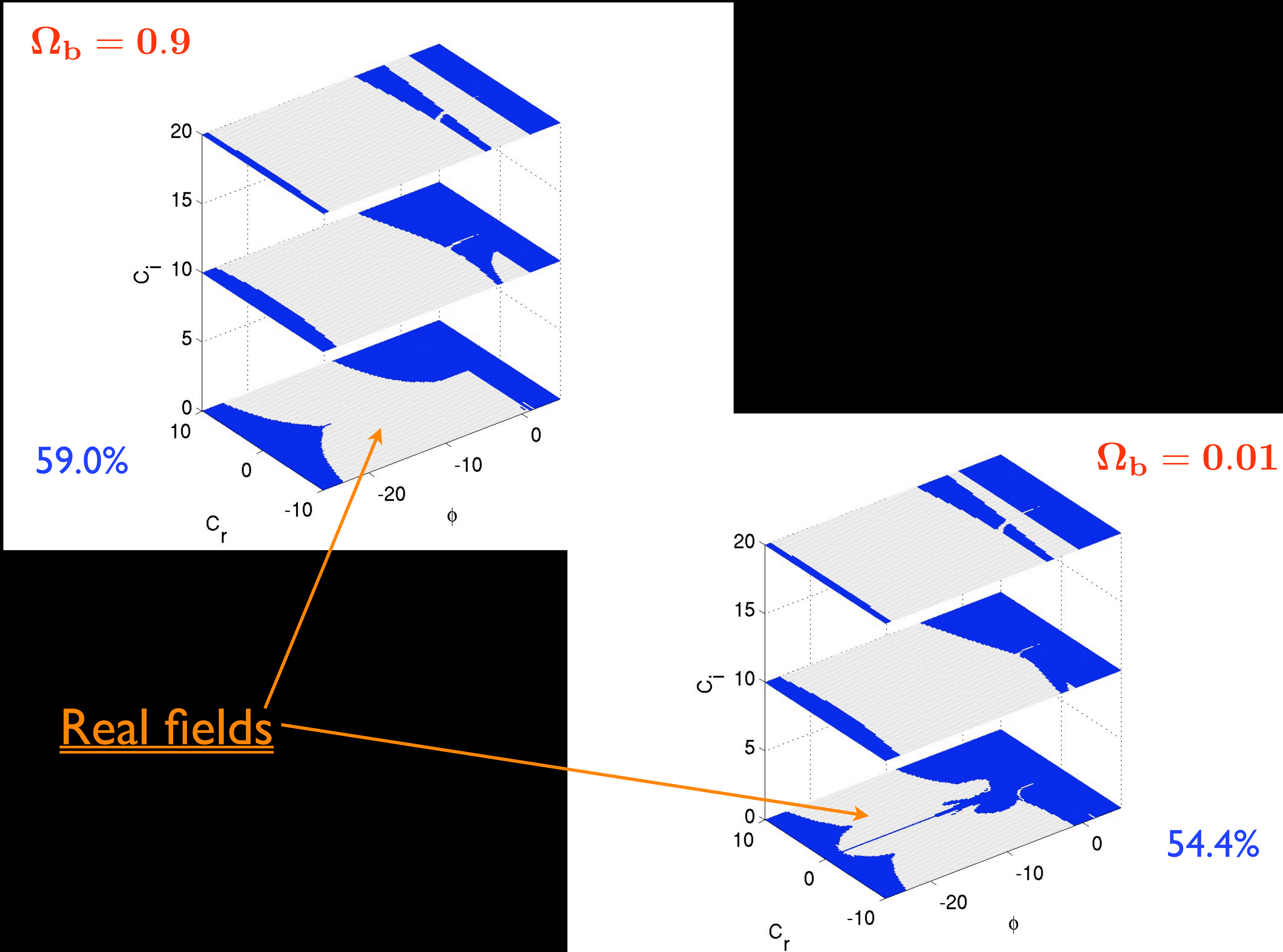


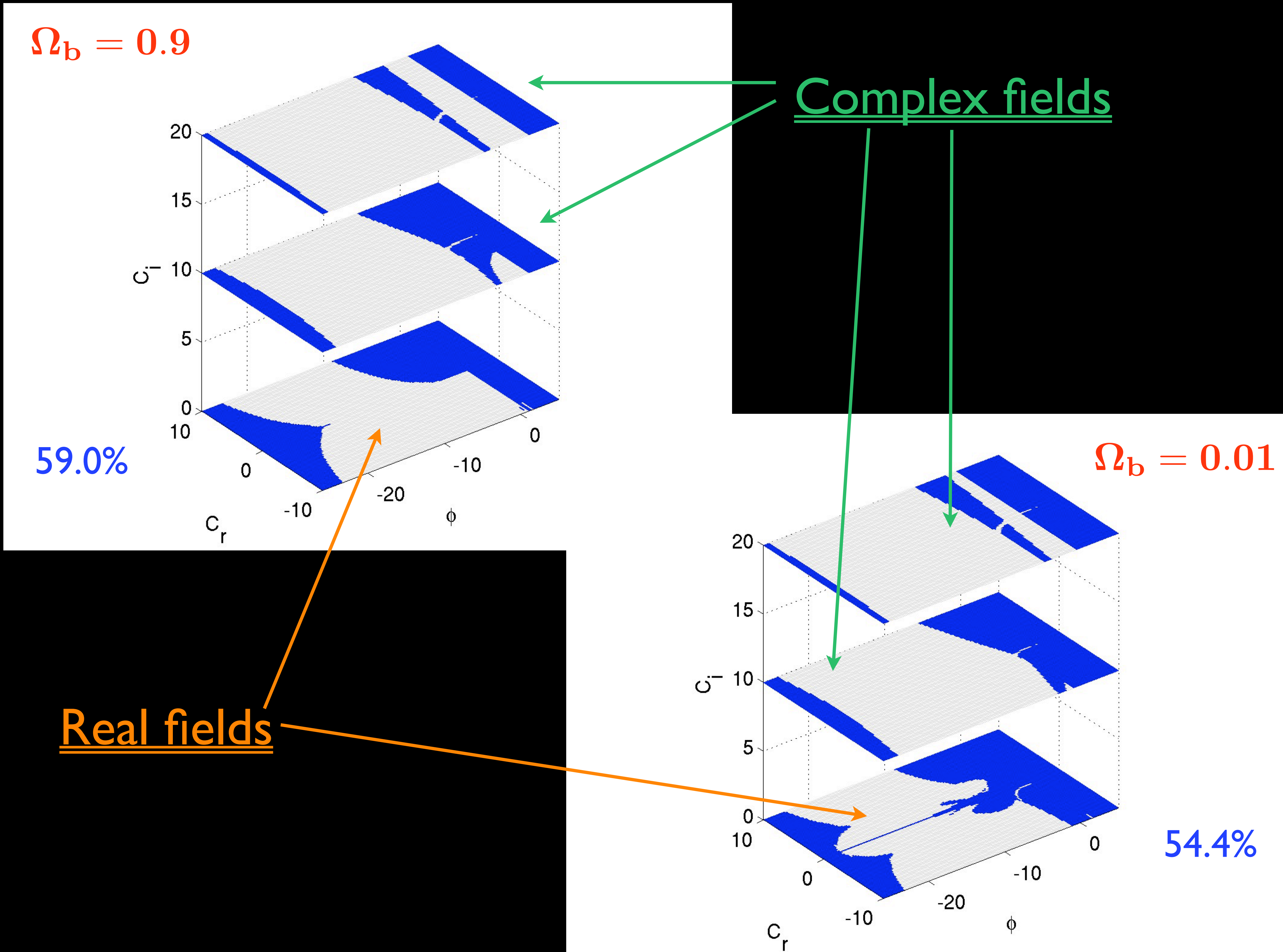
59.0%

$\Omega_b = 0.01$

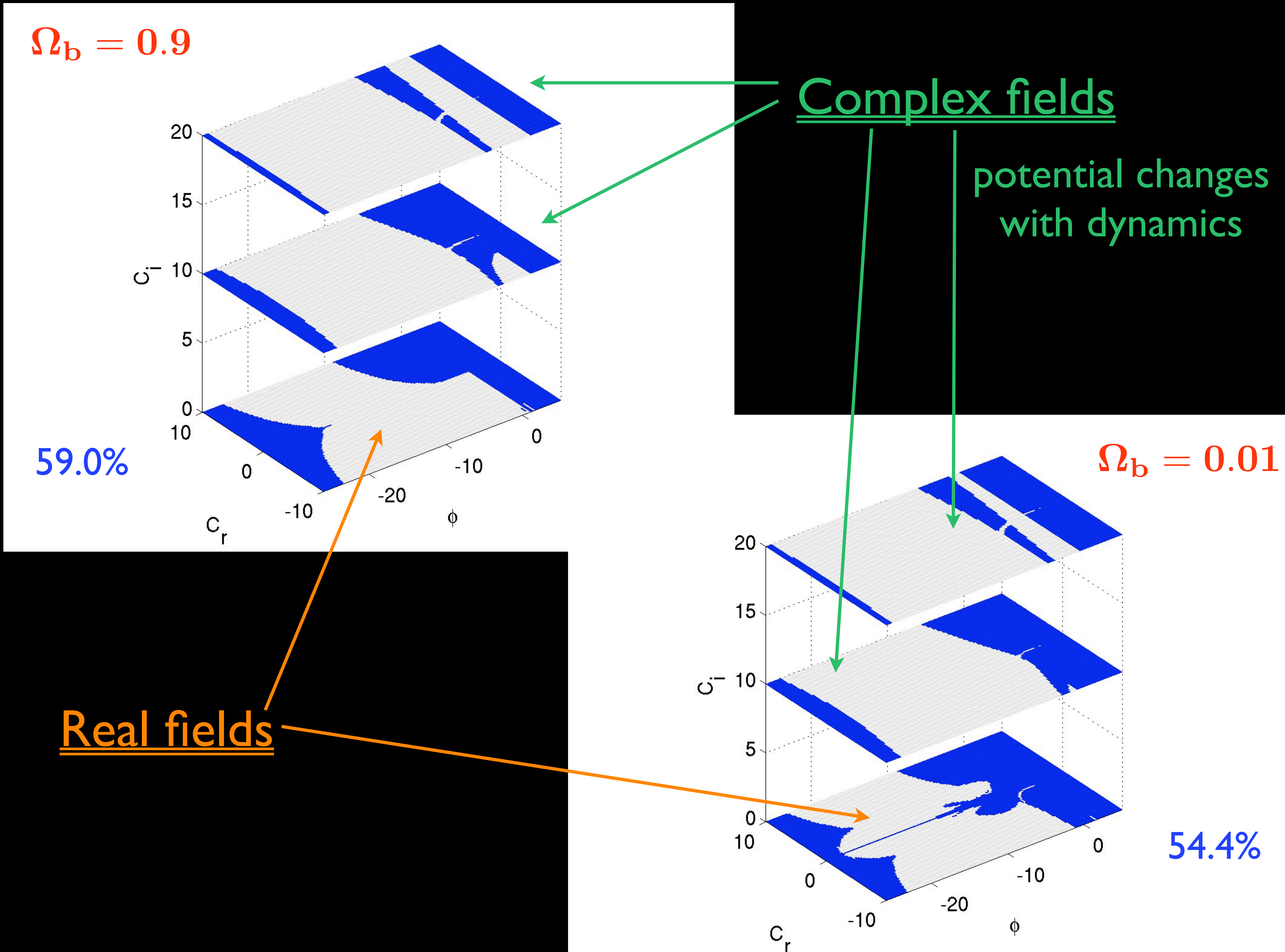


Real fields

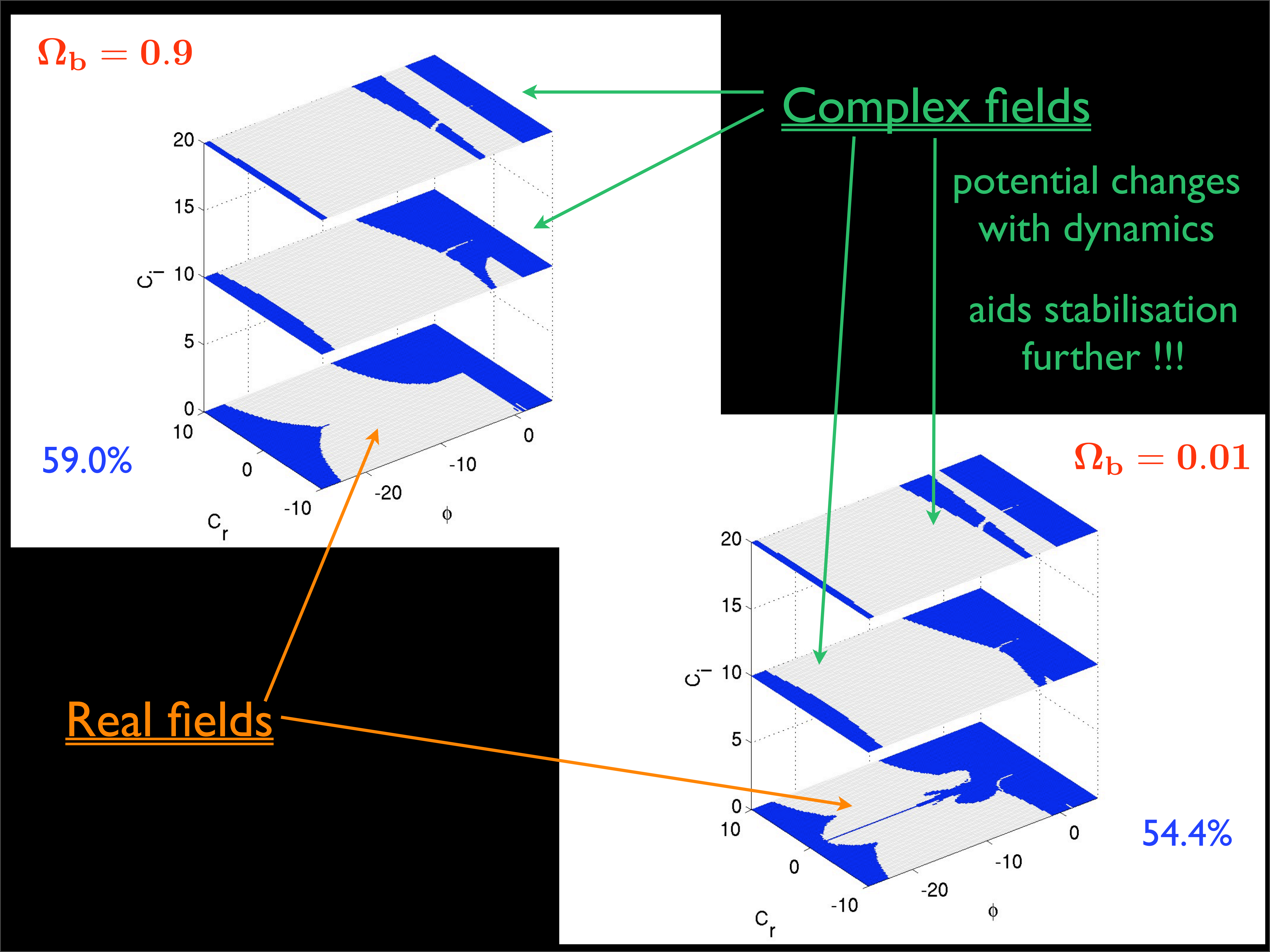

$\Omega_b = 0.9$
59.0%
c_i
20
15
10
5
0
c_r
10
0
-10
ϕ
-20
-10
0
$\Omega_b = 0.01$
54.4%
Real fields

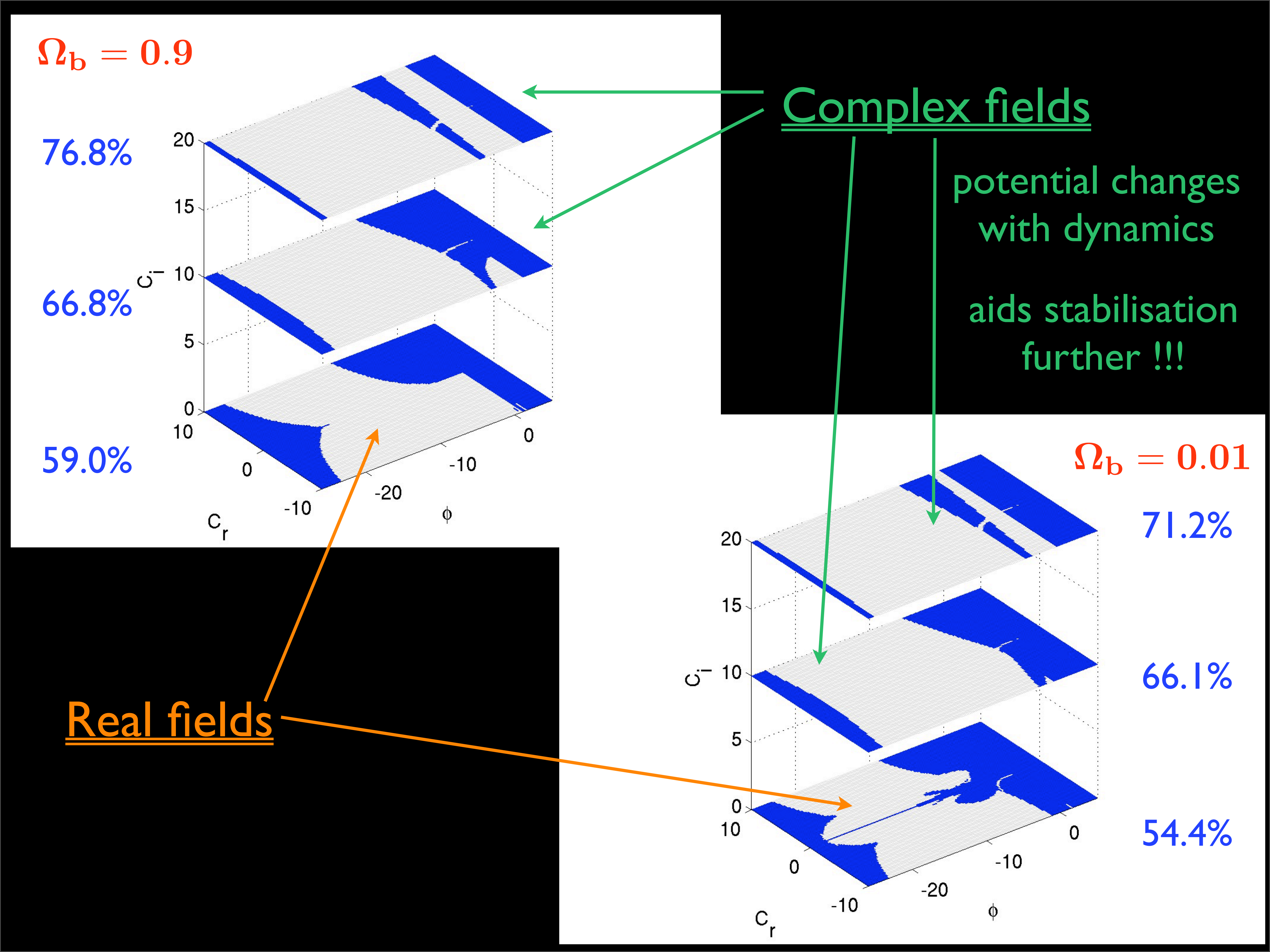


$\Omega_b = 0.9$
Complex fields
59.0%
c_i
20
15
10
5
0
10
0
-10
c_r
-20
-10
0
ϕ
Real fields
$\Omega_b = 0.01$
54.4%



$\Omega_b = 0.9$
59.0%
Complex fields
potential changes
with dynamics
$\Omega_b = 0.01$
54.4%
Real fields
c_i
c_r
ϕ


$\Omega_{\mathrm{b}} = 0.9$
Complex fields
potential changes with dynamics
aids stabilisation further !!!
59.0%
$\Omega_{\mathrm{b}} = 0.01$
54.4%
Real fields
c_i
c_r
ϕ
20
15
10
5
0
10
0
-10
-20
-10
0


$\Omega_b = 0.9$
76.8%
66.8%
59.0%
20
15
10
5
0
c_i
10
0
-10
c_r
-20
-10
0
ϕ
Complex fields
potential changes
with dynamics
aids stabilisation
further !!!
$\Omega_b = 0.01$
71.2%
66.1%
54.4%
Real fields

Summary

KKLT + Polonyi Model:

$$K = -3\ln\left(T+\bar{T}\right) + |C|^2$$

$$\mathcal{W}(C) = c + \mu^2 C$$

$$\mathcal{W}(T) = W_0 + Ae^{-\alpha T}$$

...with background fluid

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2 Real Fields - new scaling mechanism

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Background: Matter/Radiation (γ = 1 , 4/3)

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Carsten van de Bruck,
Ki-Young Choi,
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