

Challenging the Refined Swampland Distance Conjecture

Florian Wolf

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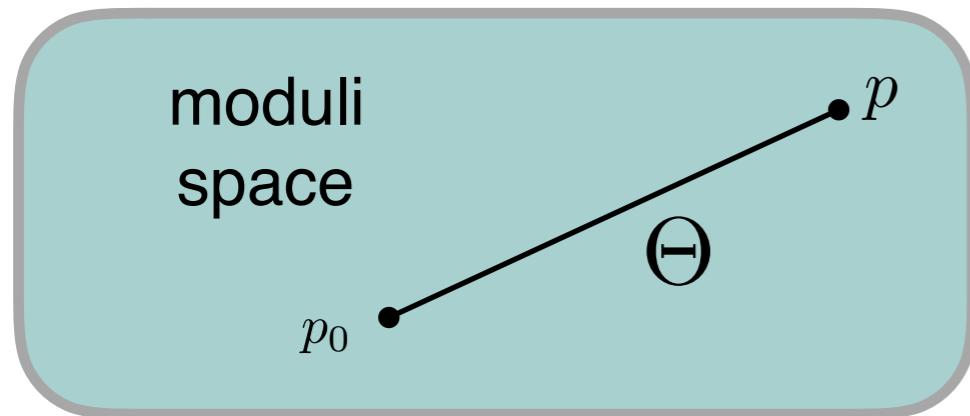


Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

based on JHEP 1806 (2018) 052 together with Ralph Blumenhagen, Daniel Kläwer
and Lorenz Schlechter

StringPheno18 Conference at University of Warsaw on July 4, 2018

Swampland Distance Conjecture ... once again



For $\Theta \rightarrow \infty$ an infinite tower of massive states becomes exponentially light: [Ooguri, Vafa '04]

$$M \sim M_0 e^{-\Theta/\Theta_\lambda}$$

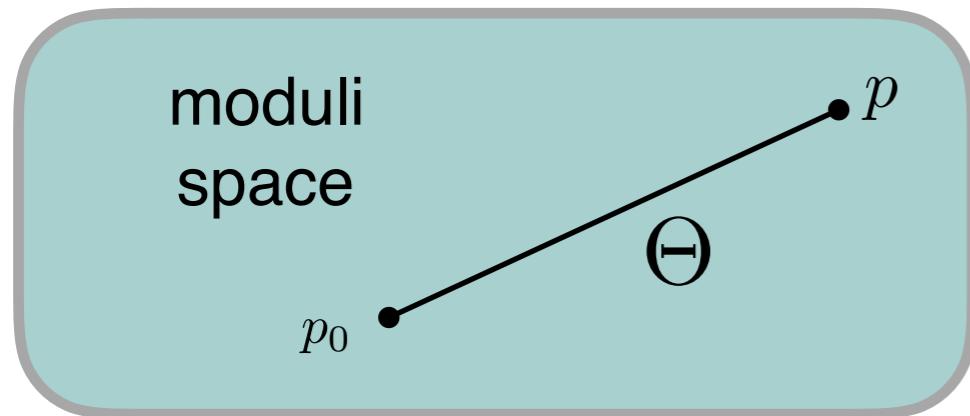
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Refined Conjecture (RSDC):

[Kläwer, Palti '17]

This effect happens already at $O(1) M_{\text{pl}}$.

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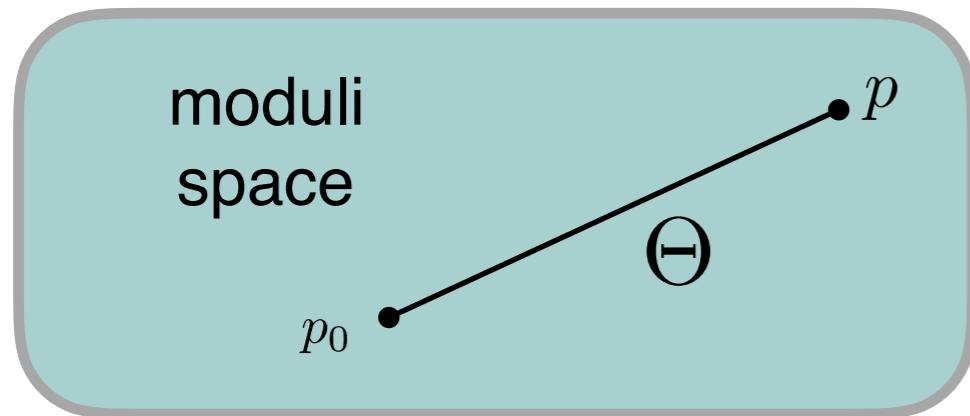
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Challenge RSDC [Blumenhagen, Kläwer, Schlechter, Wolf '18]:

States that become light: *Kaluza-Klein modes*

- finite distances without exp. light states smaller than $O(1) M_{\text{pl}}$
- infinite distances behave according to RSDC with $\Theta_\lambda < 1$

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See talk by
Daniel Kläwer

$$h^{1,1} = 1 \checkmark \quad h^{1,1} = 101 \checkmark$$

CY with $h^{1,1} = 2$

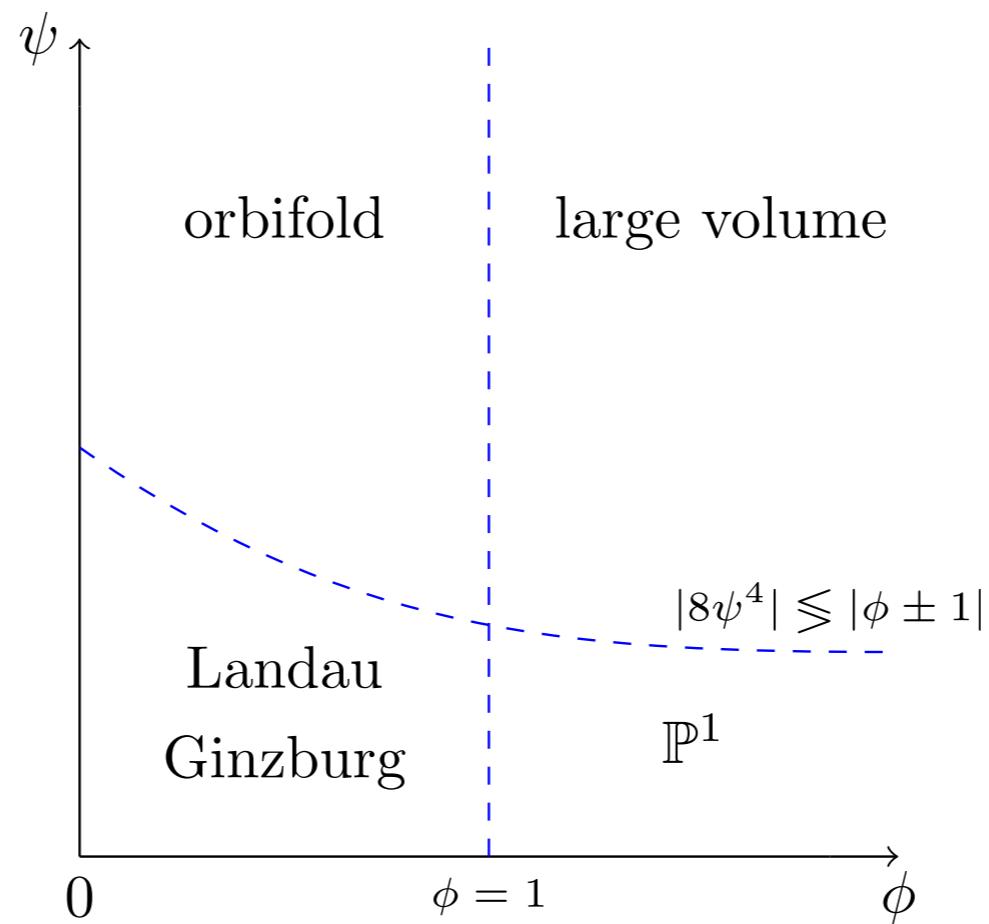
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- all phases can be analyzed

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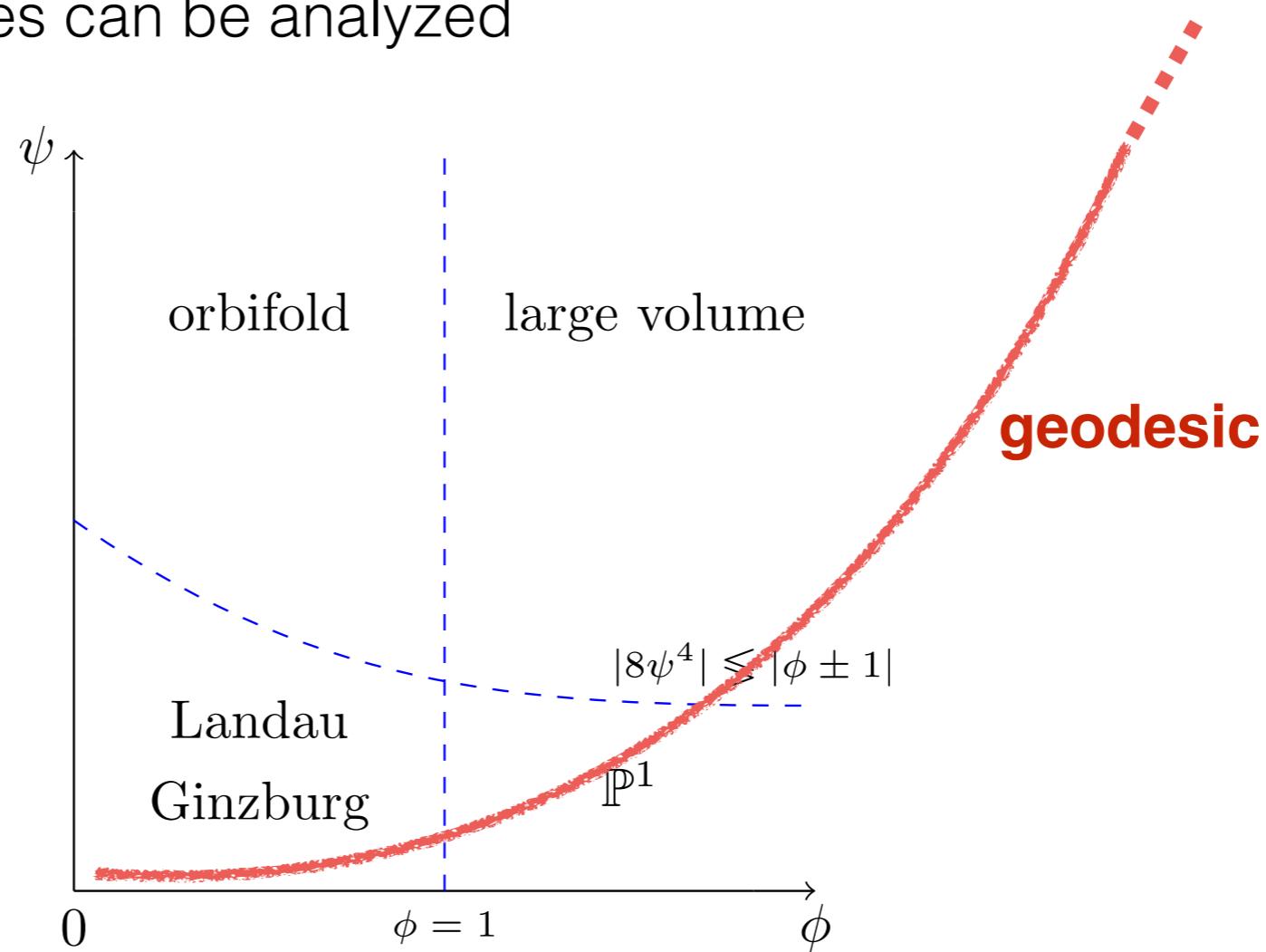


(In this figure we assume both moduli to be real for simplicity.)

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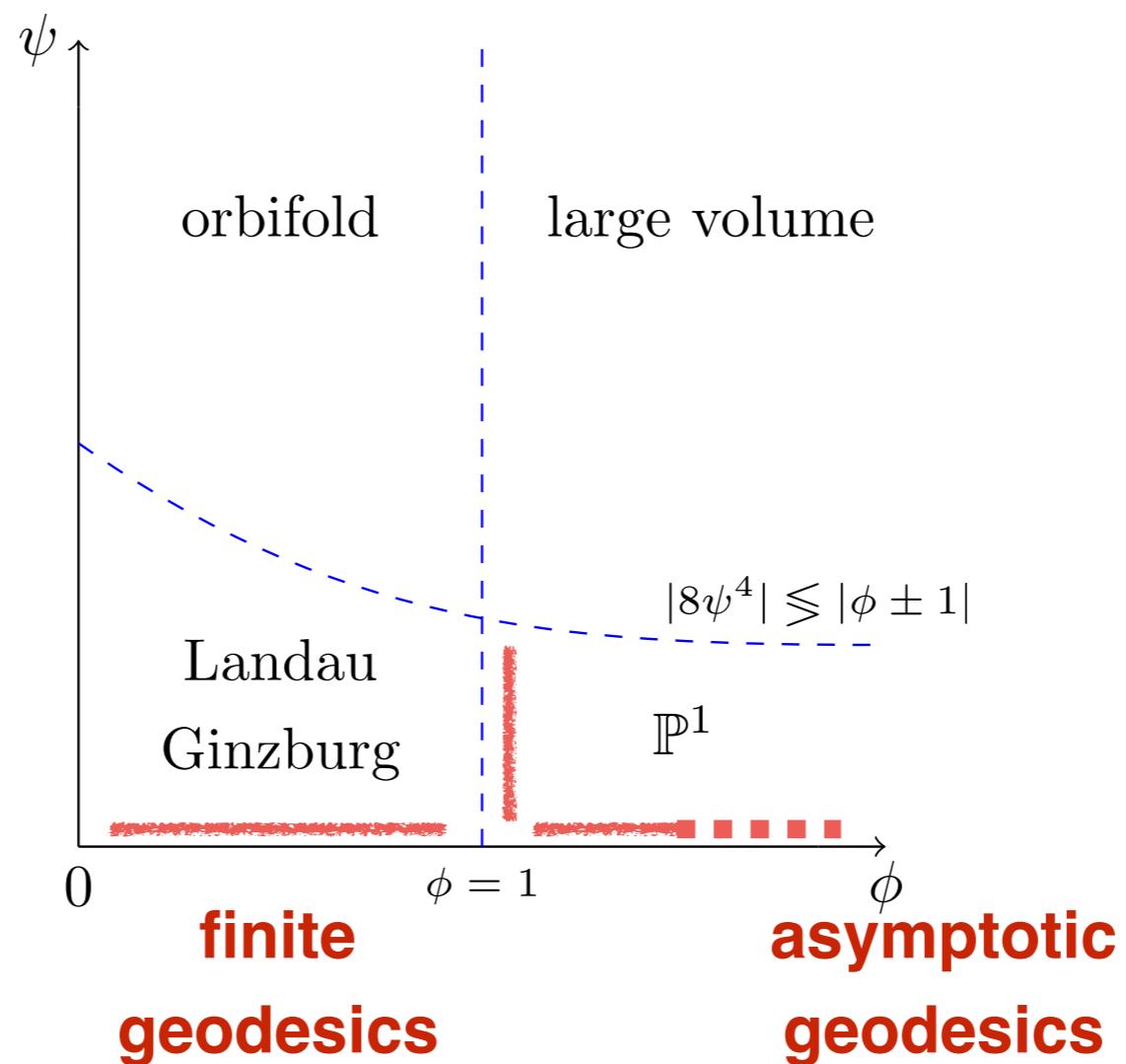


Problem: difficult to find globally shortest geodesic in real 4D space!

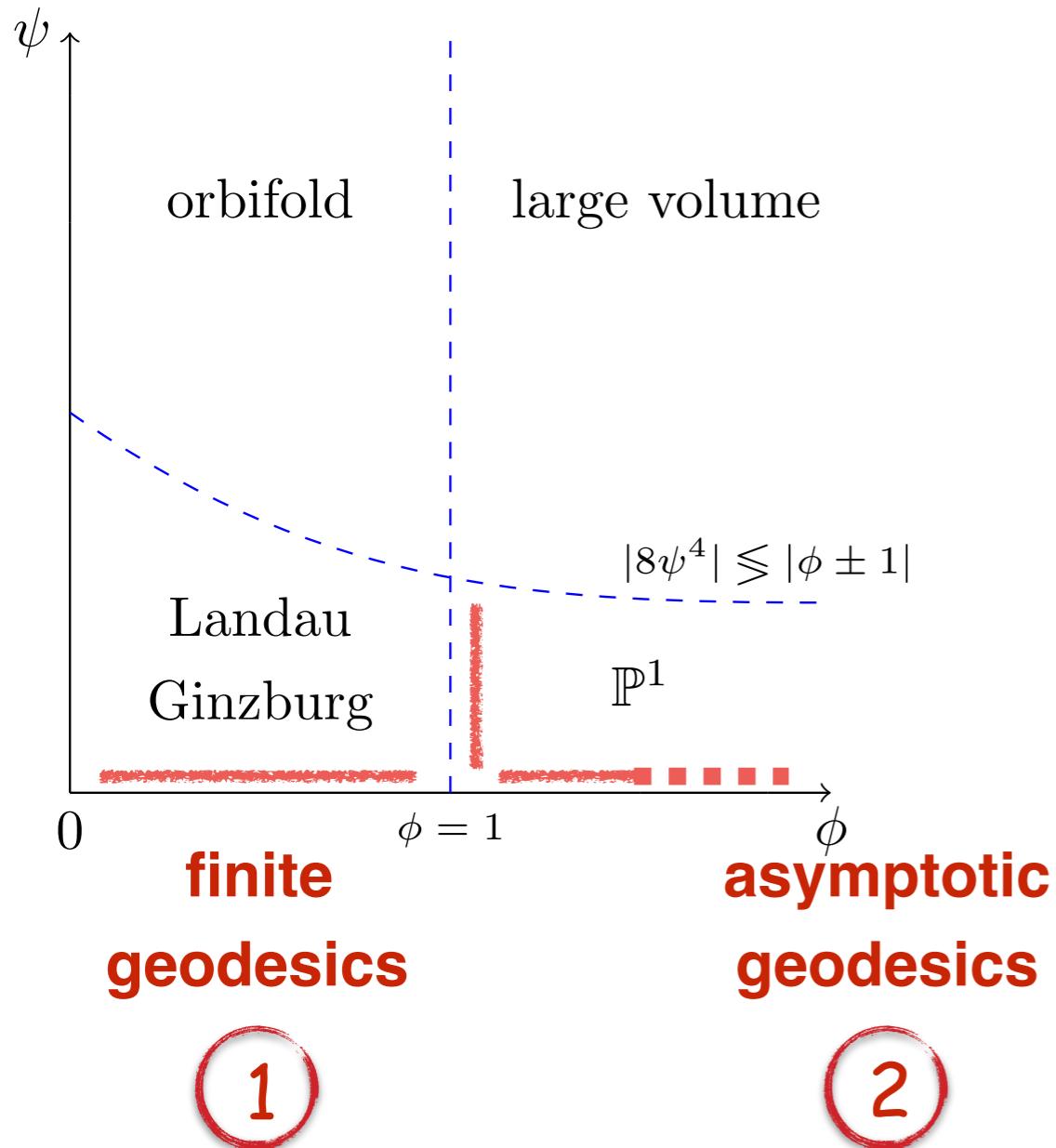
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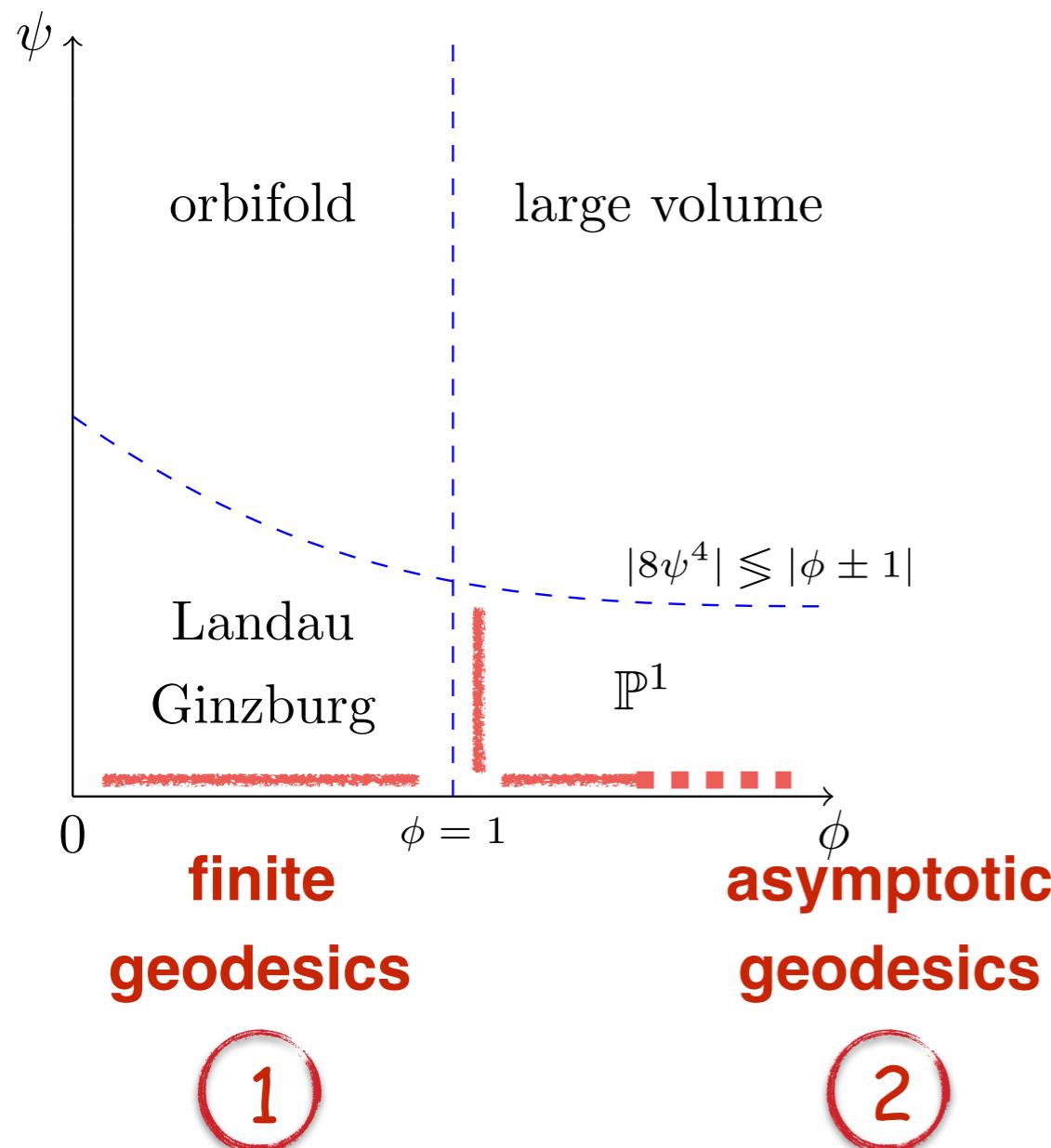
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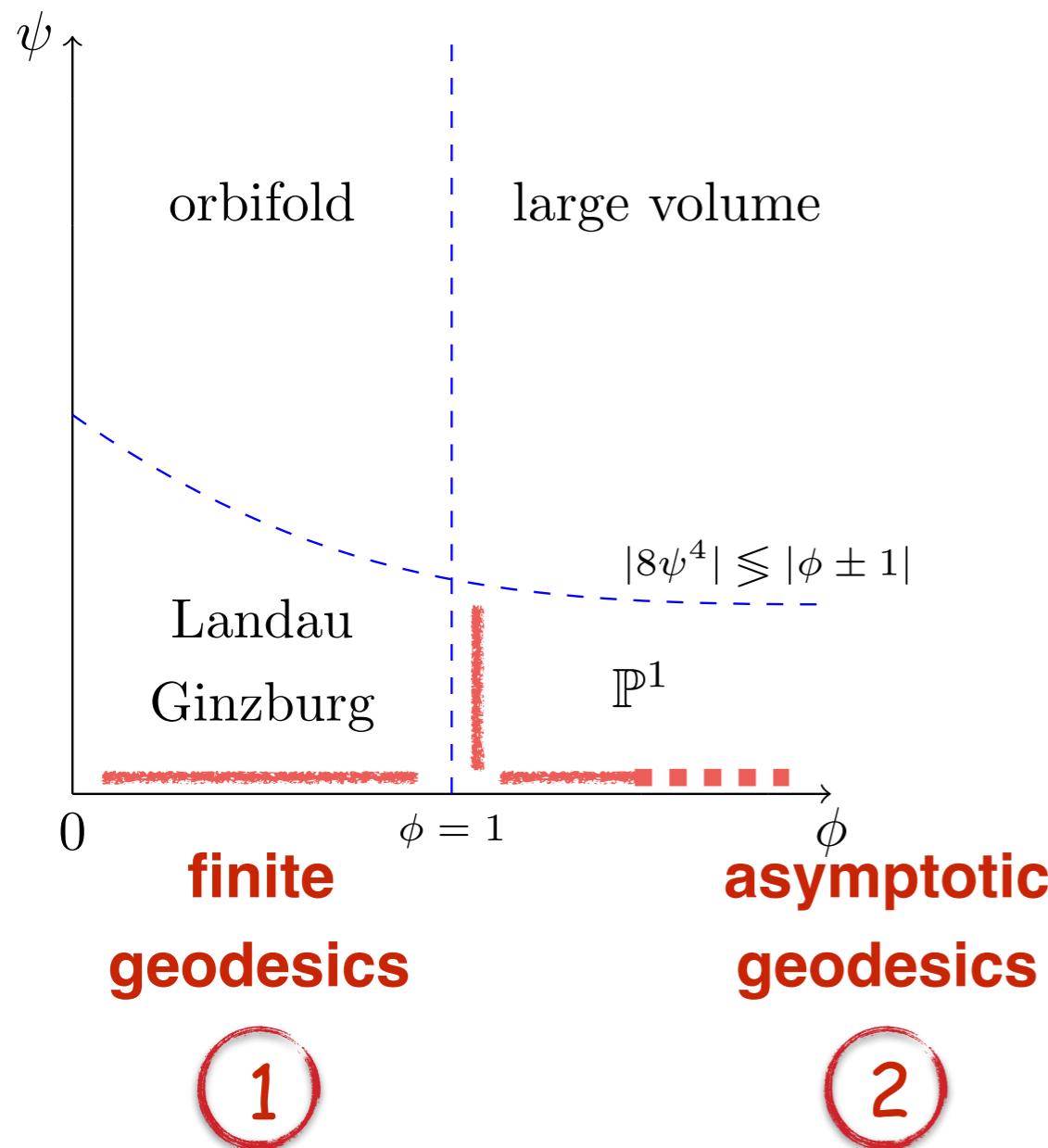
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Moduli Space for a 2-Parameter Model

Consider mirror of $P_{11222}^4[8]$ given by hypersurface constraint

$$P = x_1^8 + x_2^8 + x_3^4 + x_4^4 + x_5^4 - 8\psi x_1 x_2 x_3 x_4 x_5 - 2\phi x_1^4 x_2^4 = 0$$

[Candelas et al. '94]

complex structure moduli

\mathbb{Z}_8 symmetry on parameter space:

$$(\psi, \phi) \mapsto (\alpha\psi, -\phi) \quad \text{with} \quad \alpha = e^{\frac{2\pi i}{8}}$$

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Metric $G = \partial_t \partial_{\bar{t}} K$ from Kähler potential $K = -\log \left[-i \bar{\Pi} \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \Pi \right]$

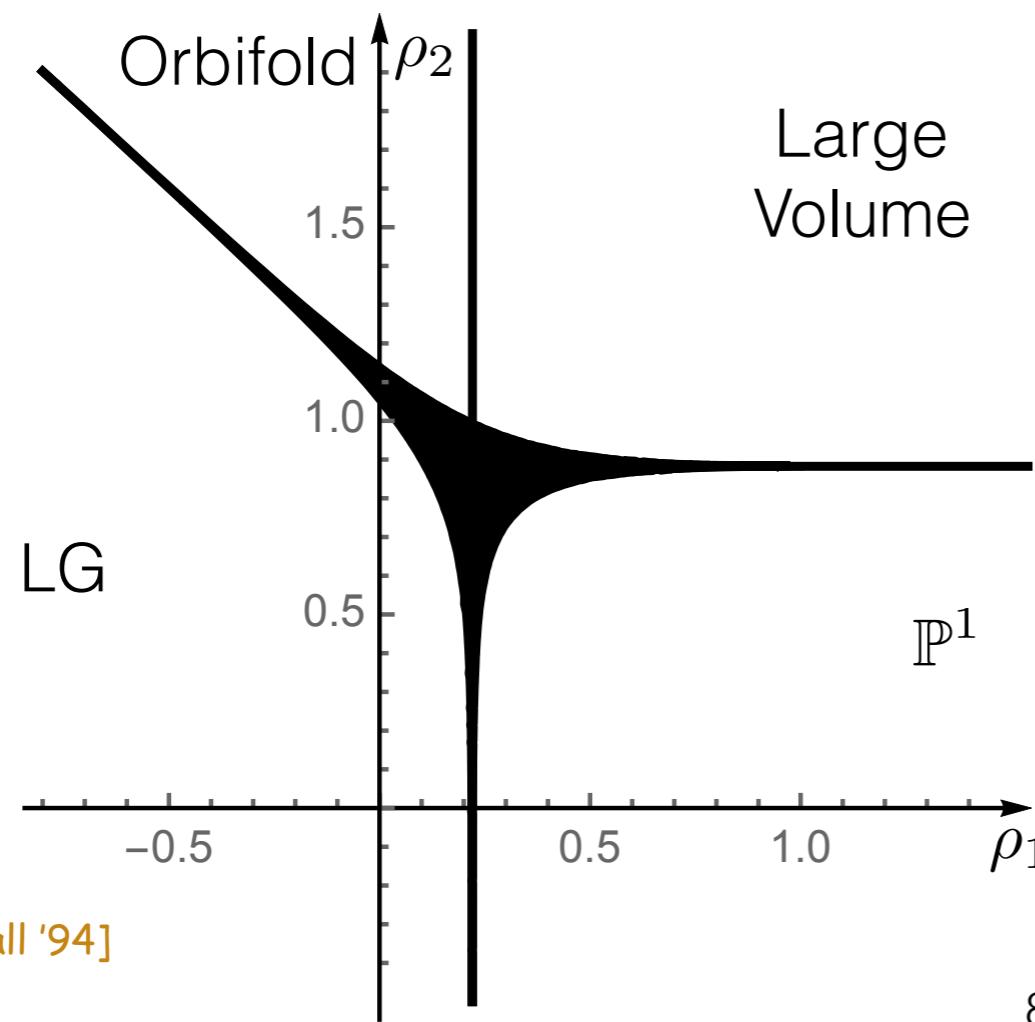
Phases of the Moduli Space

Kähler potential via period vector $\Pi(\psi) = m \cdot \omega(\psi)$

[Candelas et al. '94]

transformation to sympl. basis

periods



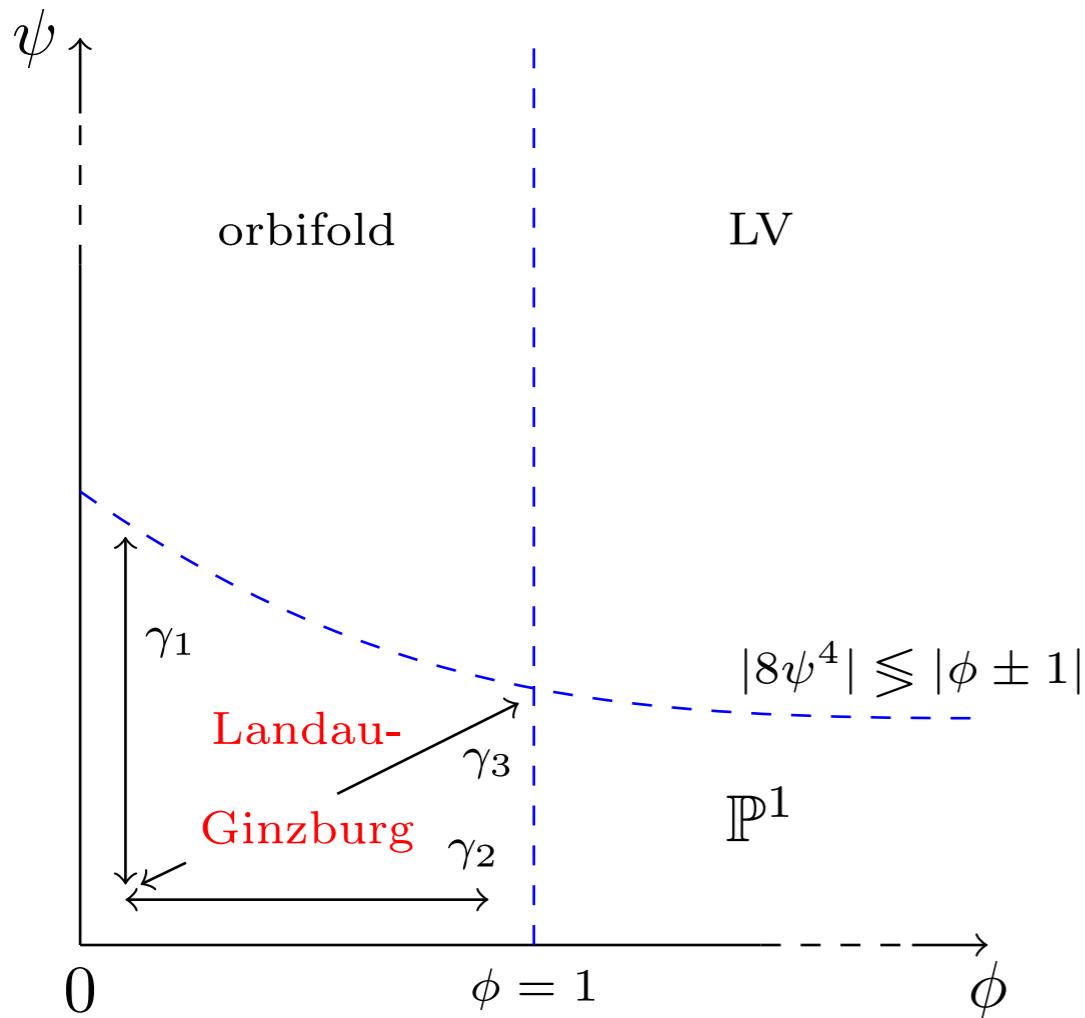
**4 different phases
separated by singularities**

$$\rho_1 = \frac{1}{2\pi} \log |4\phi^2|$$

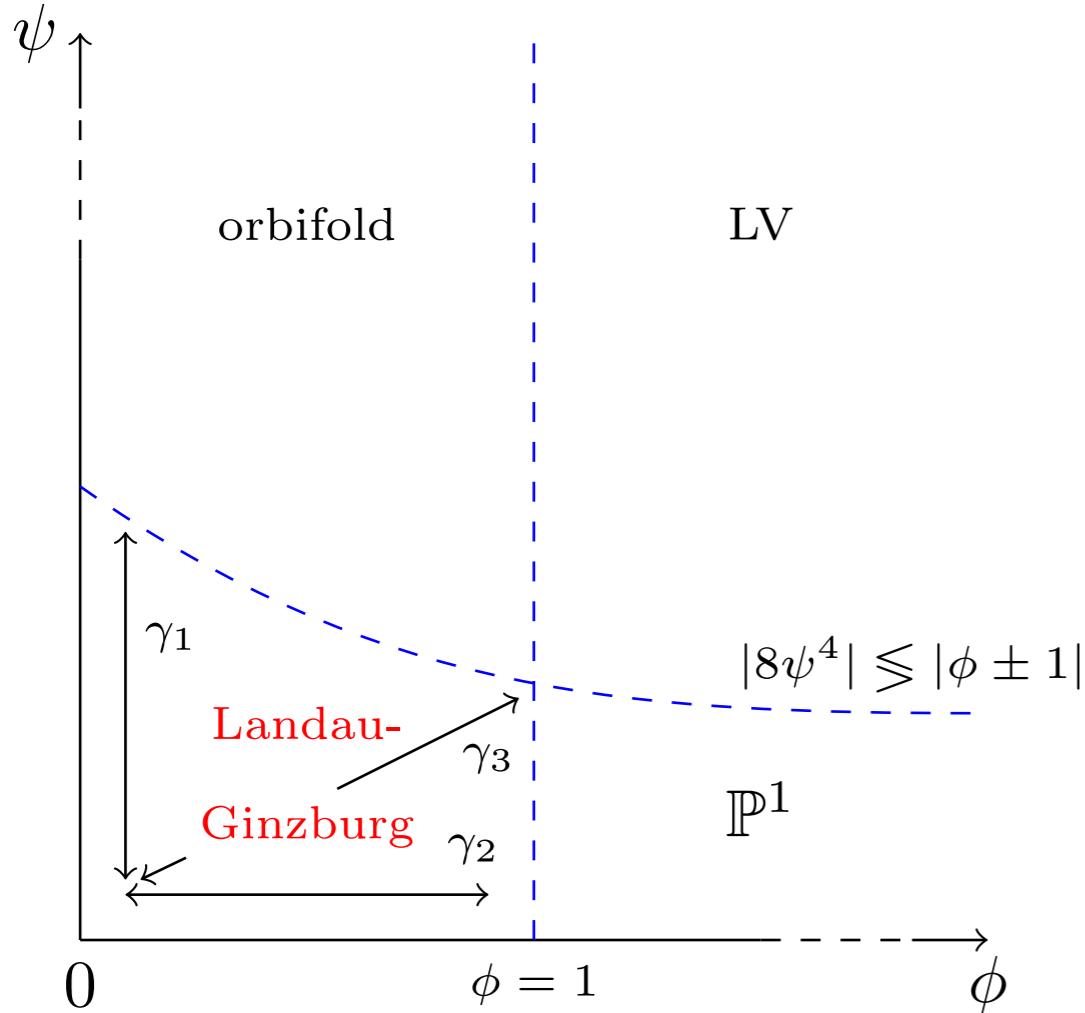
$$\rho_2 = \frac{1}{2\pi} \log \left| \frac{2^{11} \psi^4}{\phi} \right|$$

[Aspinwall '94]

LG Phase



LG Phase



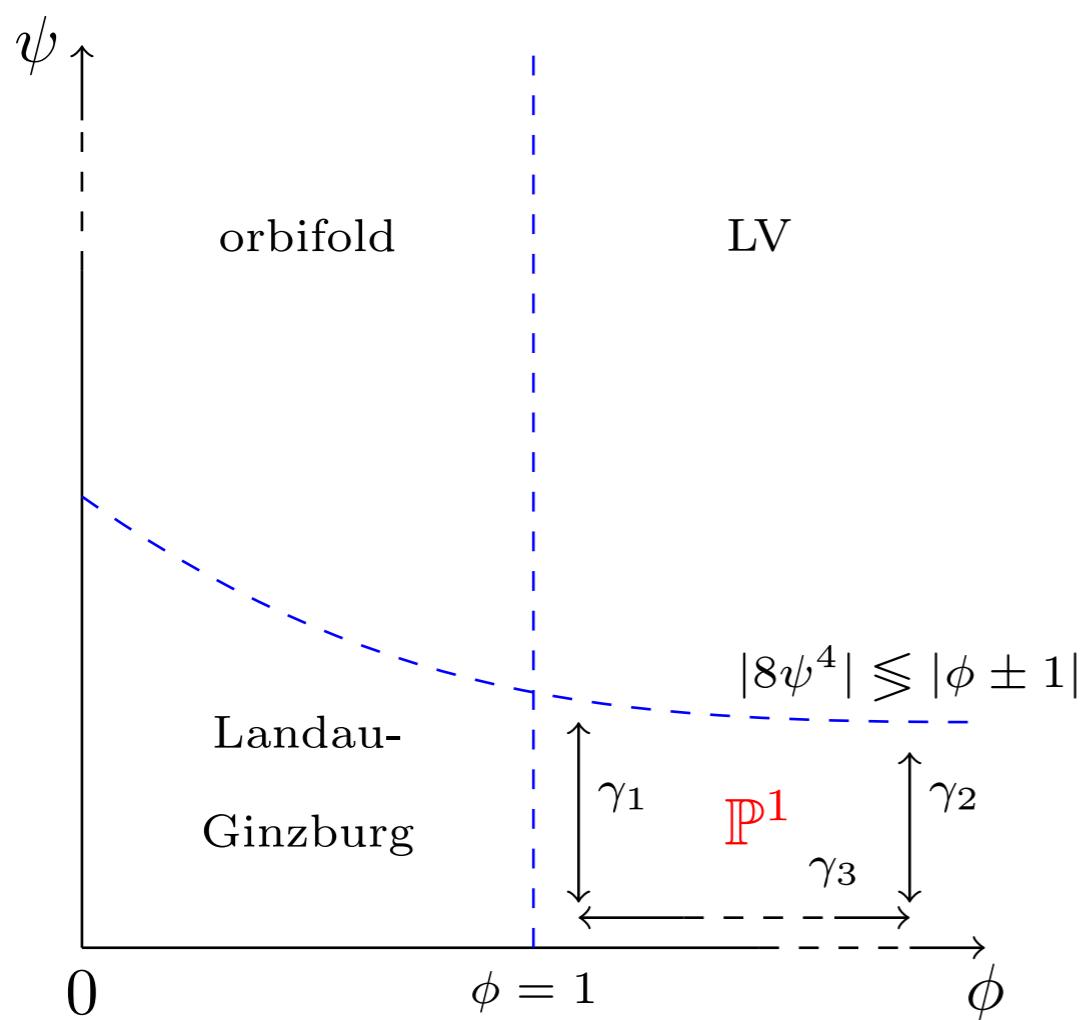
$$\Delta\Theta_1 = \int_{\gamma_1} d\psi \sqrt{G_{\psi\bar{\psi}}(\psi)} = 0.40,$$

$$\Delta\Theta_2 = \int_{\gamma_2} d\phi \sqrt{G_{\phi\bar{\phi}}(\phi)} = 0.24,$$

$$\begin{aligned} \Delta\Theta_3 &= \int_{\gamma_3} d\tau \sqrt{G_{\mu\bar{\nu}}(\psi(\tau), \phi(\tau))} \frac{dx^\mu}{d\tau} \frac{d\bar{x}^{\bar{\nu}}}{d\tau} \\ &= 0.36 \end{aligned}$$

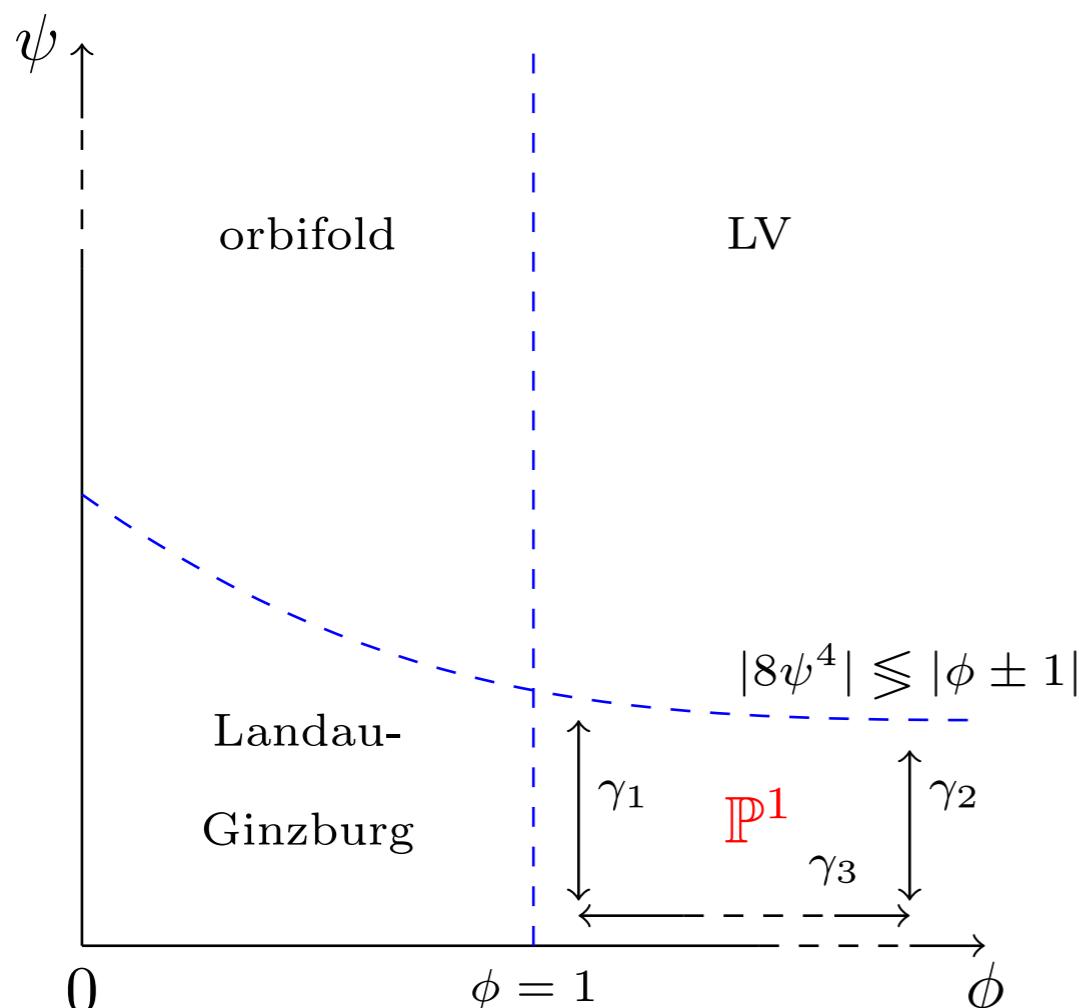
*Finite distances are all smaller than 1
and thus in agreement with RSDC ✓*

Hybrid Phase 1



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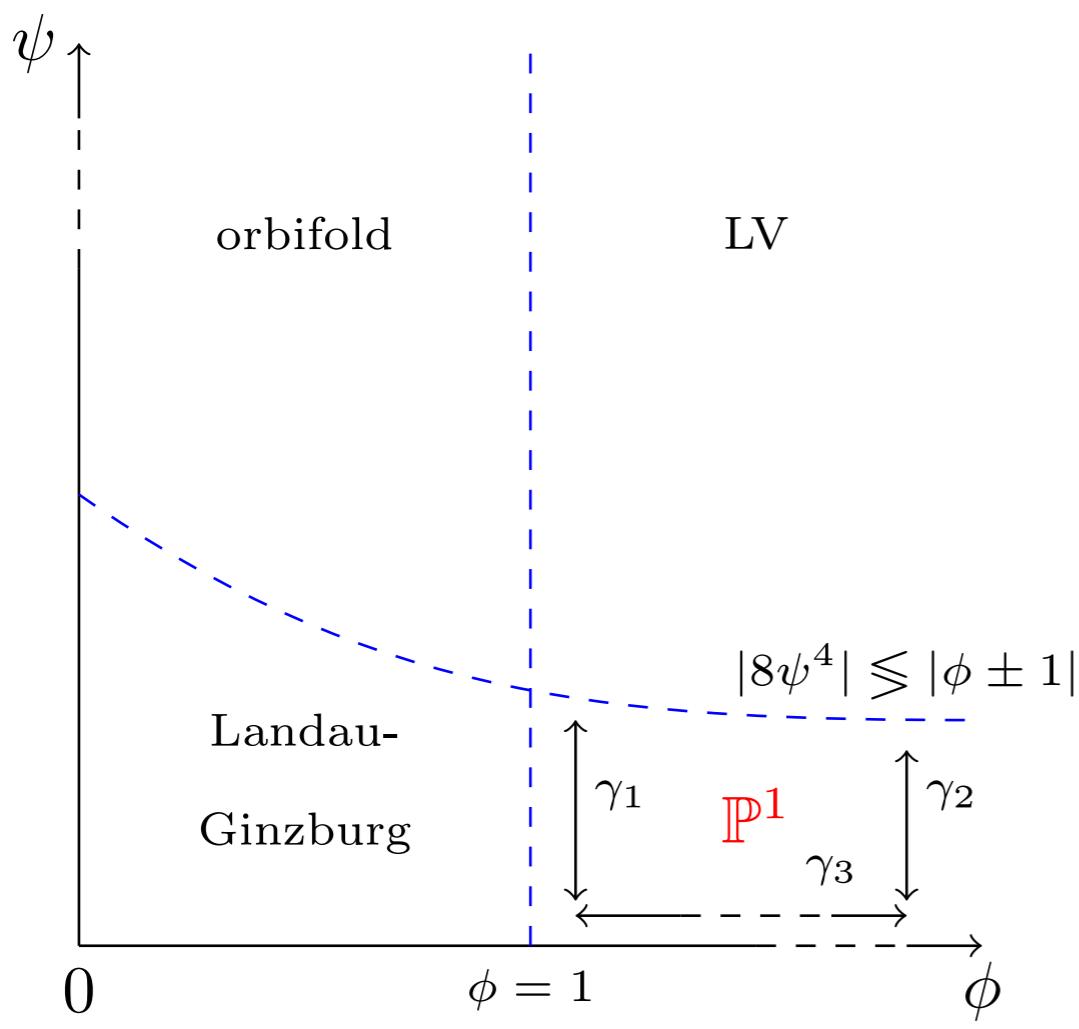
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Asymptotic behaviour:

$$G_{\mathbb{P}^1}^{\text{asym}} \simeq \begin{pmatrix} \frac{0.25}{|\phi|^2 (\log |\phi|)^2} & 0 \\ 0 & \frac{0.5905}{\sqrt{|\phi|}} \end{pmatrix}$$

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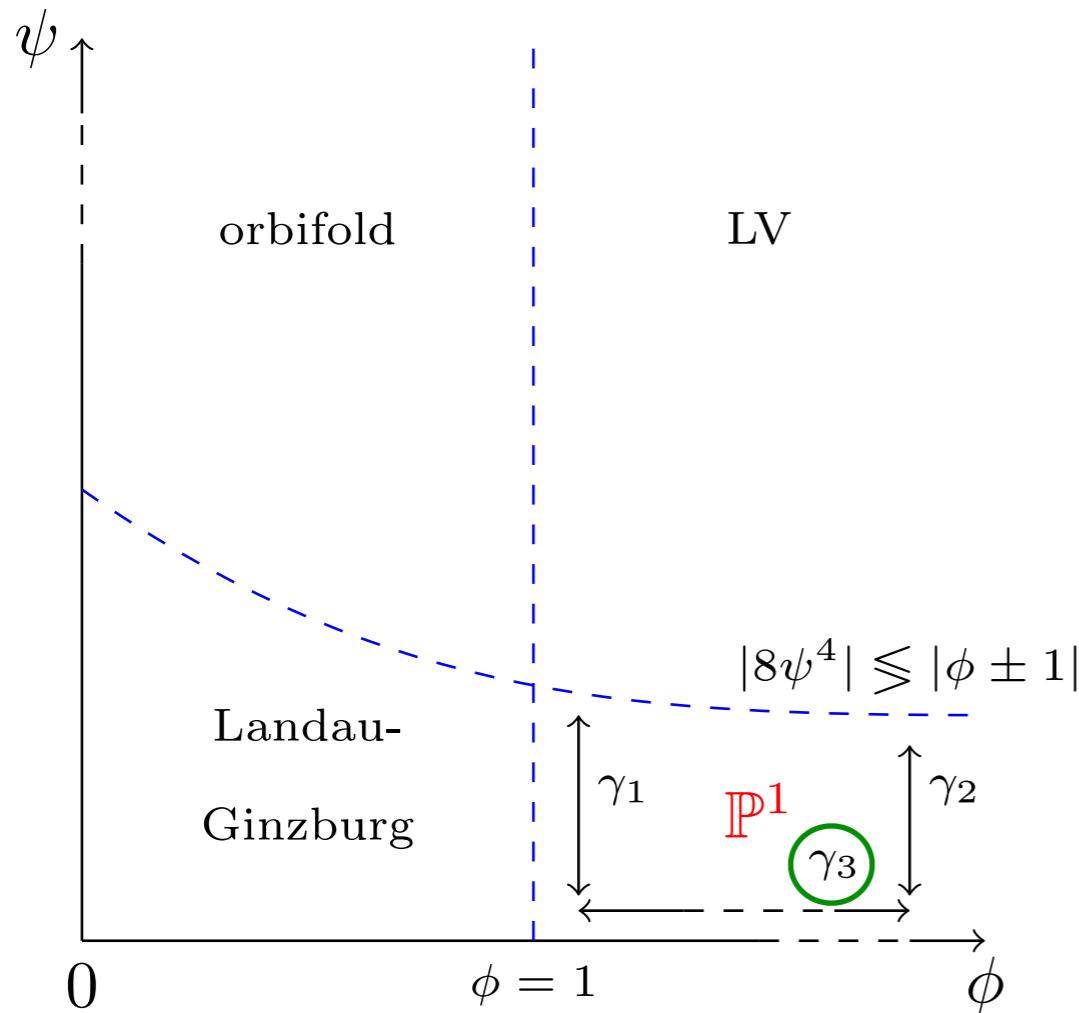
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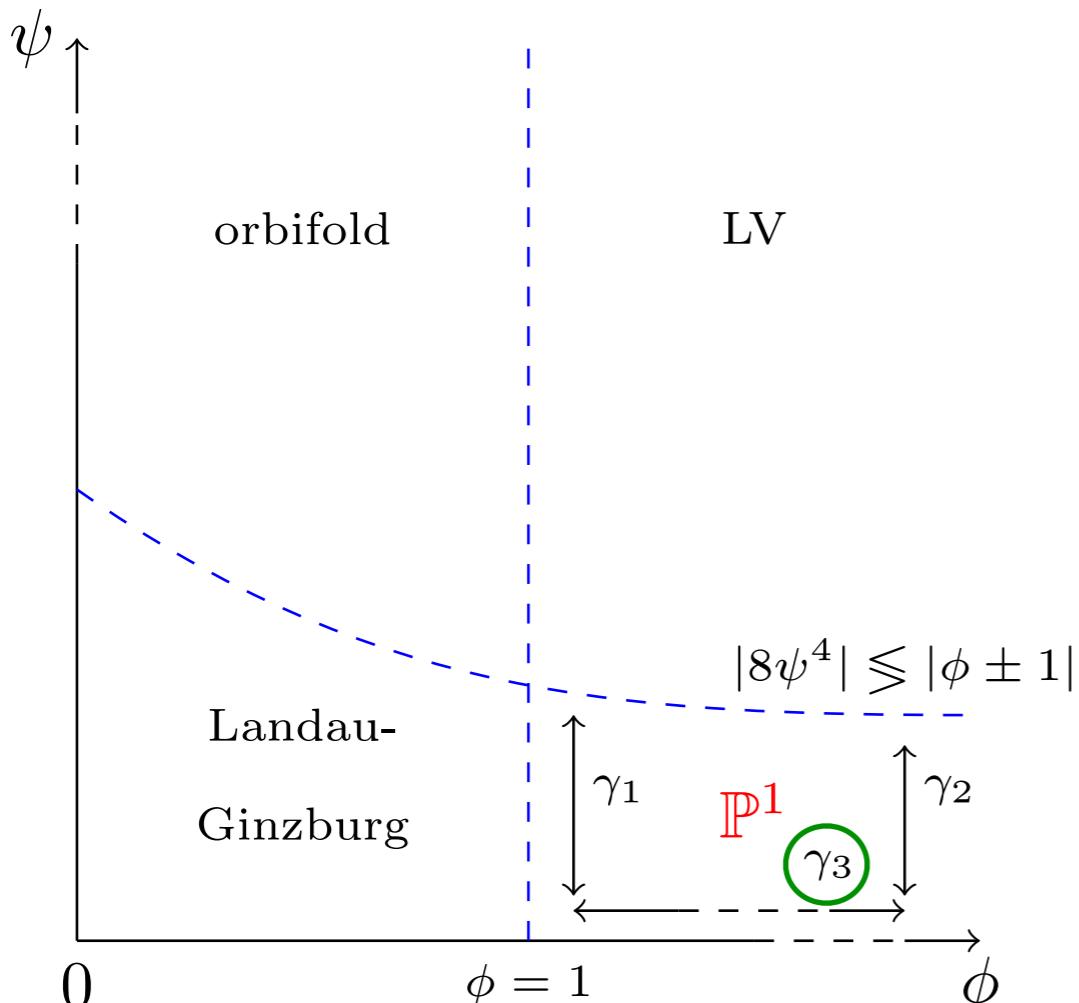
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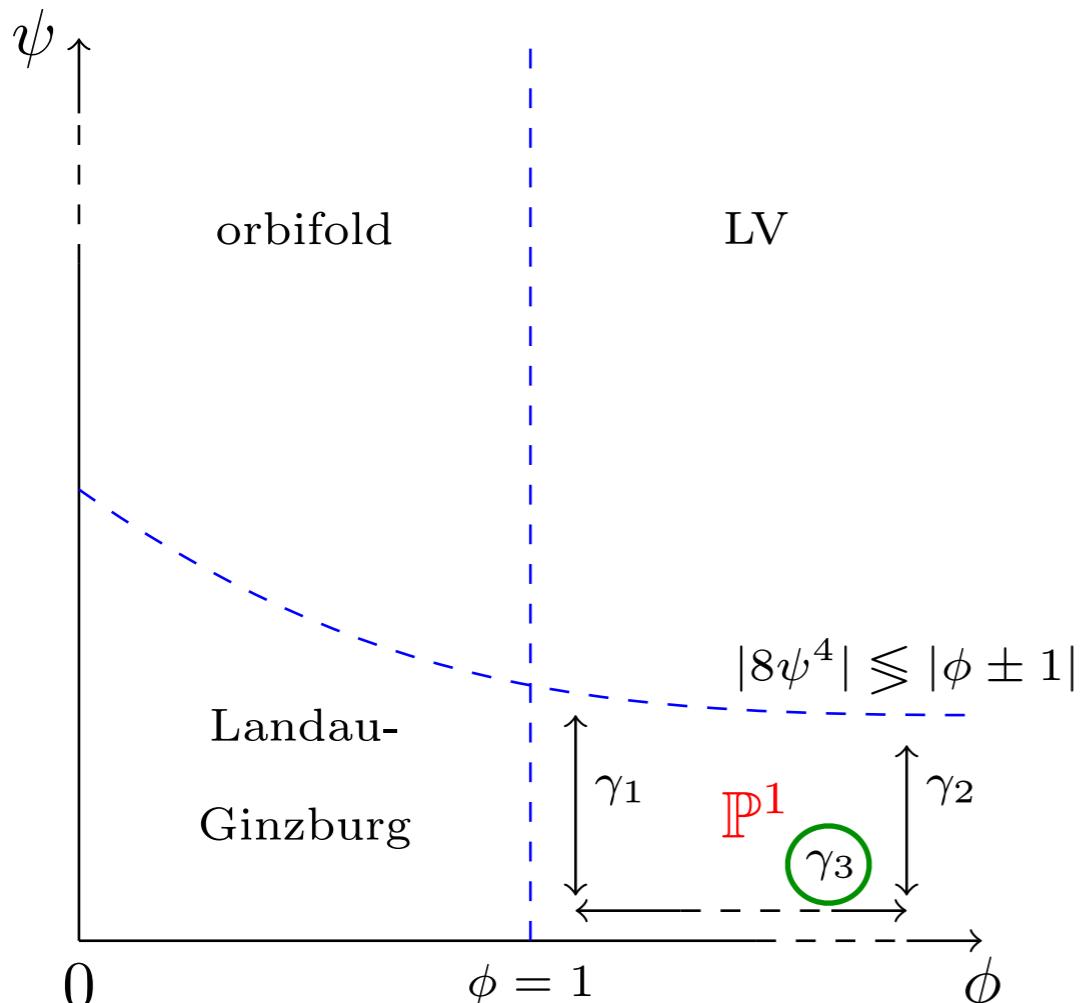
$$\Theta \sim \log(\log \phi) \sim \log(\text{Im } t_2)$$

Mirror map

$$t_1 \simeq \frac{1}{2}(-1 + i) + \dots ,$$

$$t_2 \simeq \left(1 - \frac{i}{2}\right) + \frac{8i \log(2)}{2\pi} + \frac{i}{\pi} \log(\phi) + \dots$$

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Asymptotic Geodesics

P1 hybrid phase

→ geodesic equations for asymptotic regime $\psi \approx 0, \phi \rightarrow \infty$

$$\begin{aligned} \frac{d^2\phi}{d\tau^2} + \Gamma_{\phi\phi}^\phi \left(\frac{d\phi}{d\tau} \right)^2 &= 0 \\ \frac{d^2\psi}{d\tau^2} + \Gamma_{\phi\phi}^\psi \left(\frac{d\phi}{d\tau} \right)^2 &= 0 \end{aligned} \quad \text{with} \quad G_{\mathbb{P}^1}^{\text{asym}} \simeq \begin{pmatrix} \frac{0.25}{|\phi|^2 (\log |\phi|)^2} & 0 \\ 0 & \frac{0.5905}{\sqrt{|\phi|}} \end{pmatrix}$$

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together with the proper distance $\Theta = \int_\gamma d\tau \sqrt{G_{\mathbb{P}^1, \phi\bar{\phi}}^{\text{asym}} \left(\frac{d\phi}{d\tau} \right)^2} = \frac{1}{2} C_1 \tau$

In Agreement with the RSDC:

$$\text{Im}(t_2) = -\frac{1}{2} + \frac{8 \log 2}{2\pi} + \frac{1}{\pi} \exp (2\Theta + C_1 C_2) \rightarrow \Theta_\lambda = 0.5 \lesssim O(1) \quad \checkmark$$

Conclusion

- systematic study of distances in CY moduli spaces to challenge the Refined Swampland Distance Conjecture
- many more models (1, 2, 101 - Parameter) in paper, in particular $\mathbb{P}_{11226}^4[12]$, $\mathbb{P}_{11169}^4[18]$ are analogous to $\mathbb{P}_{11222}^4[8]$

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Results:

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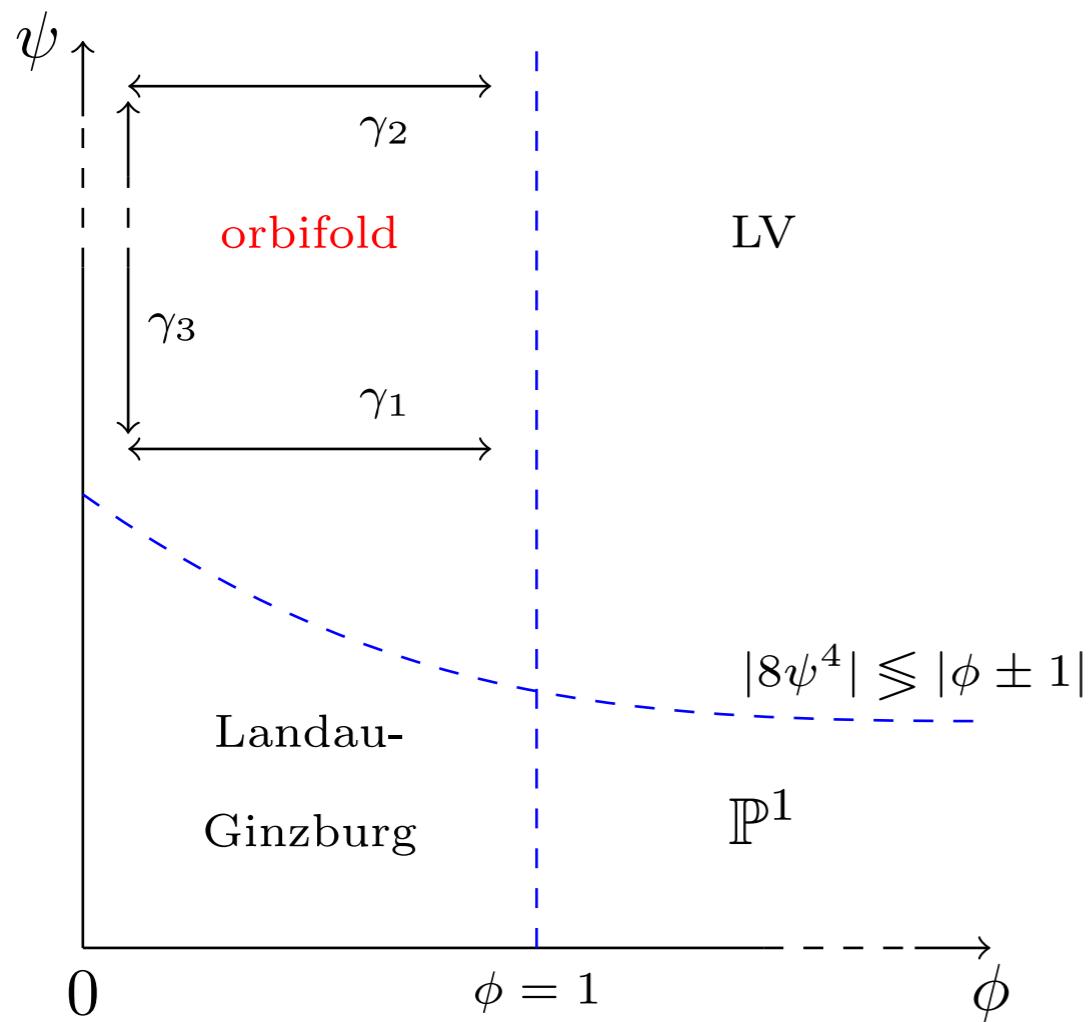
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*Thank
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Wolf's Conjecture: Life in the Swampland is also fun!

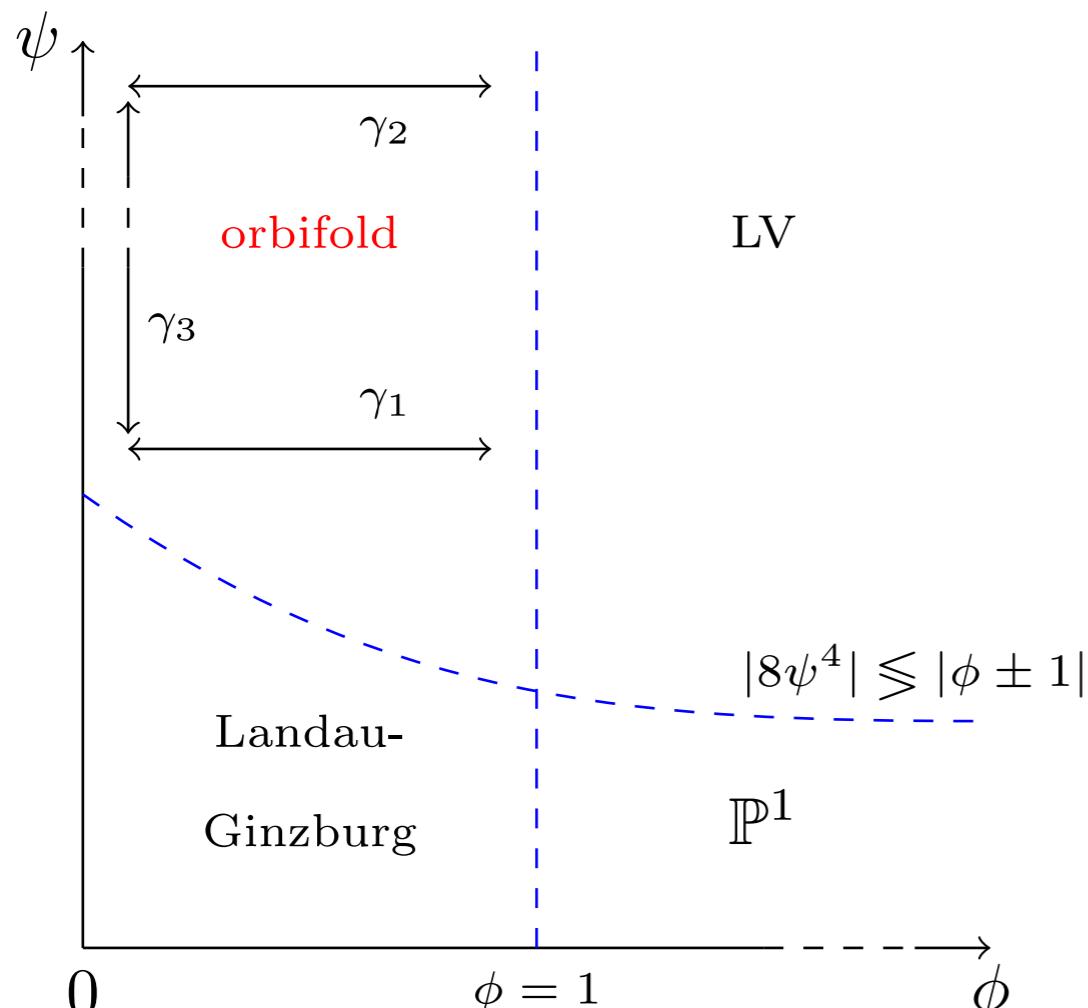
Backup Slides

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$$\Delta\Theta_1 = \int_{\gamma_1} d\phi \sqrt{G_{\phi\bar{\phi}}(\phi)} = 0.21$$

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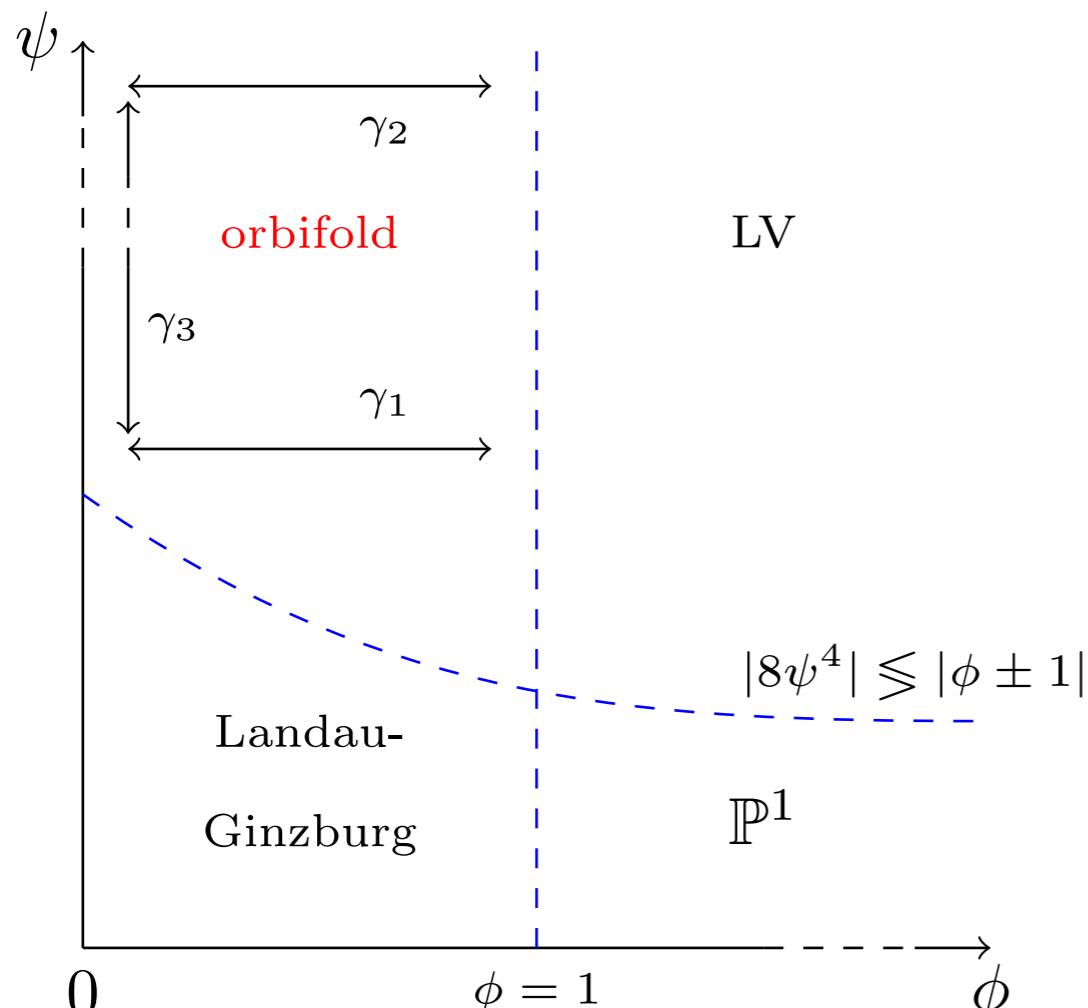
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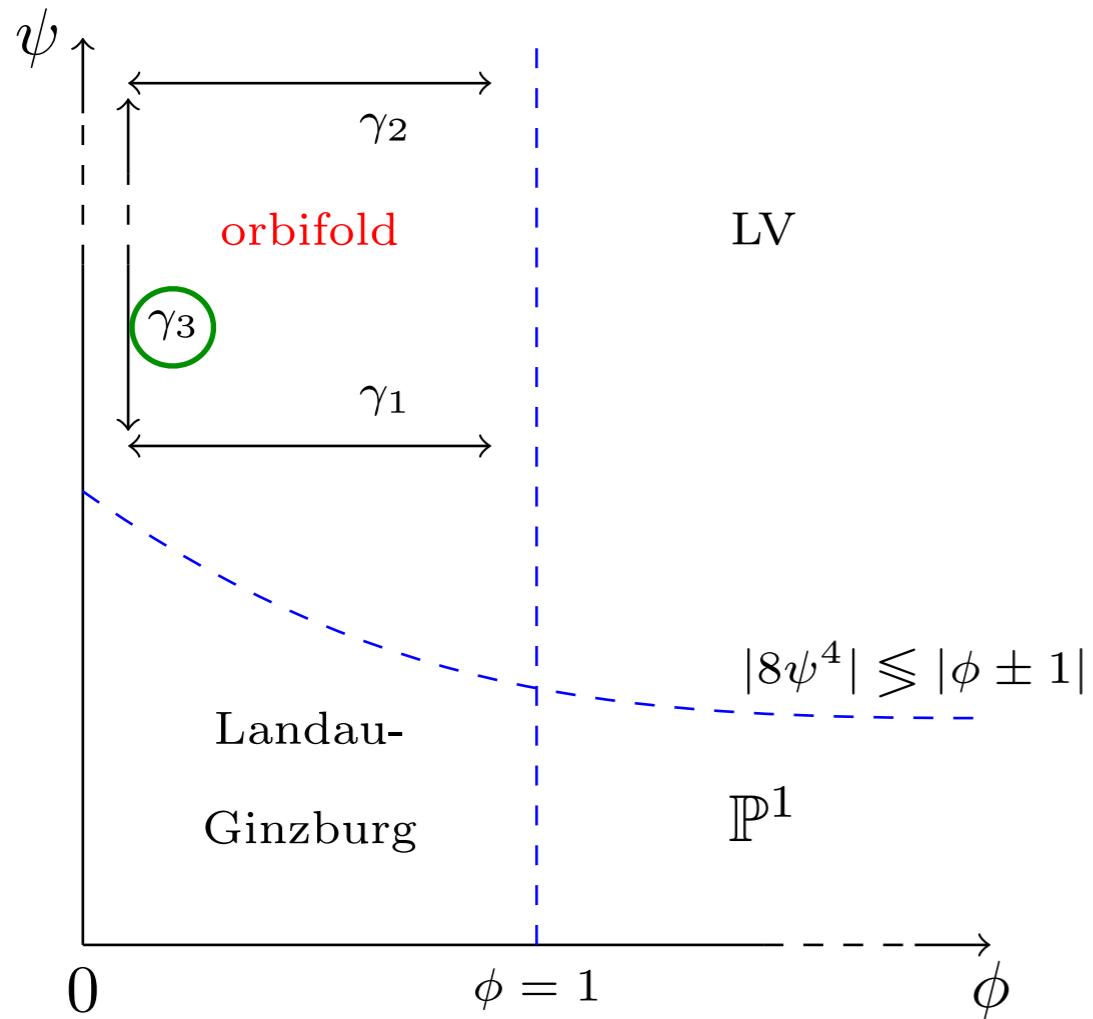
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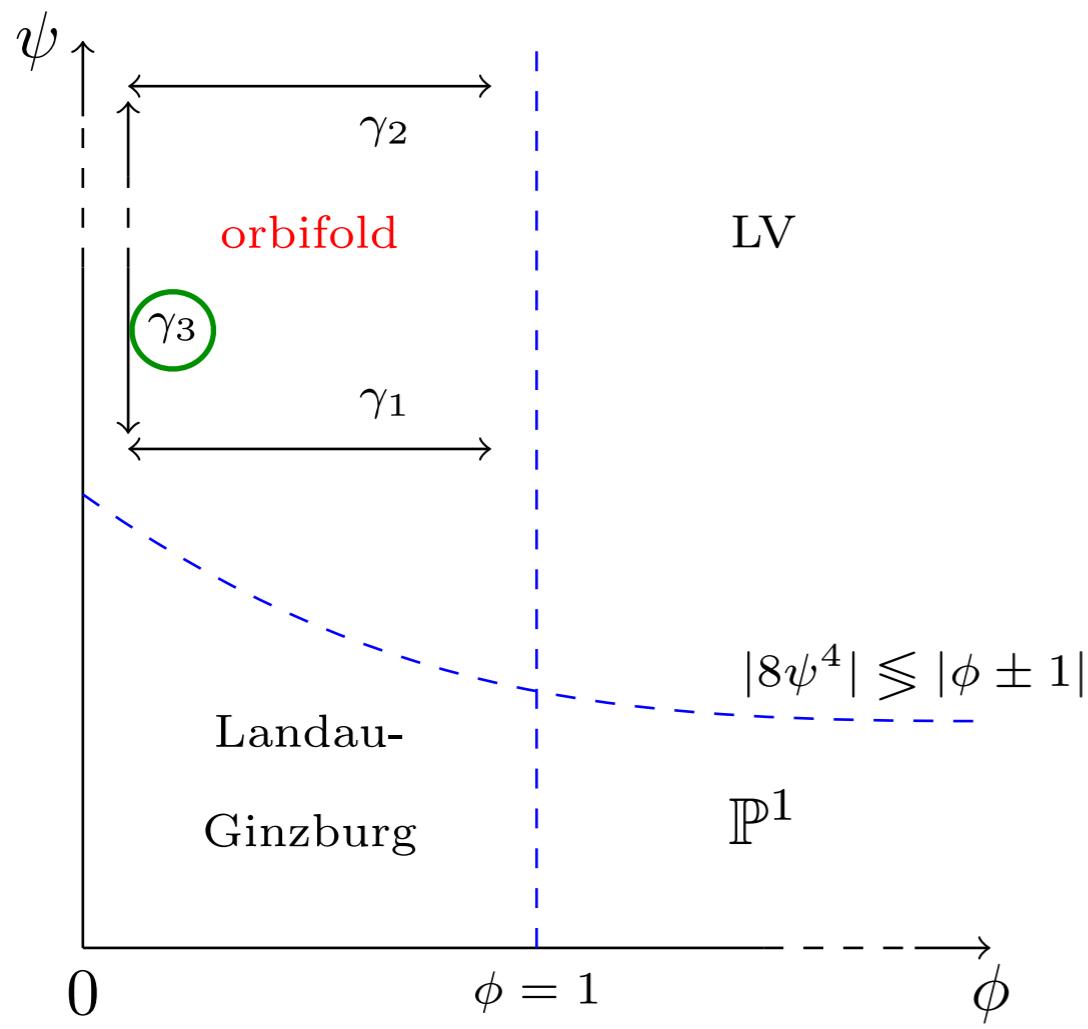
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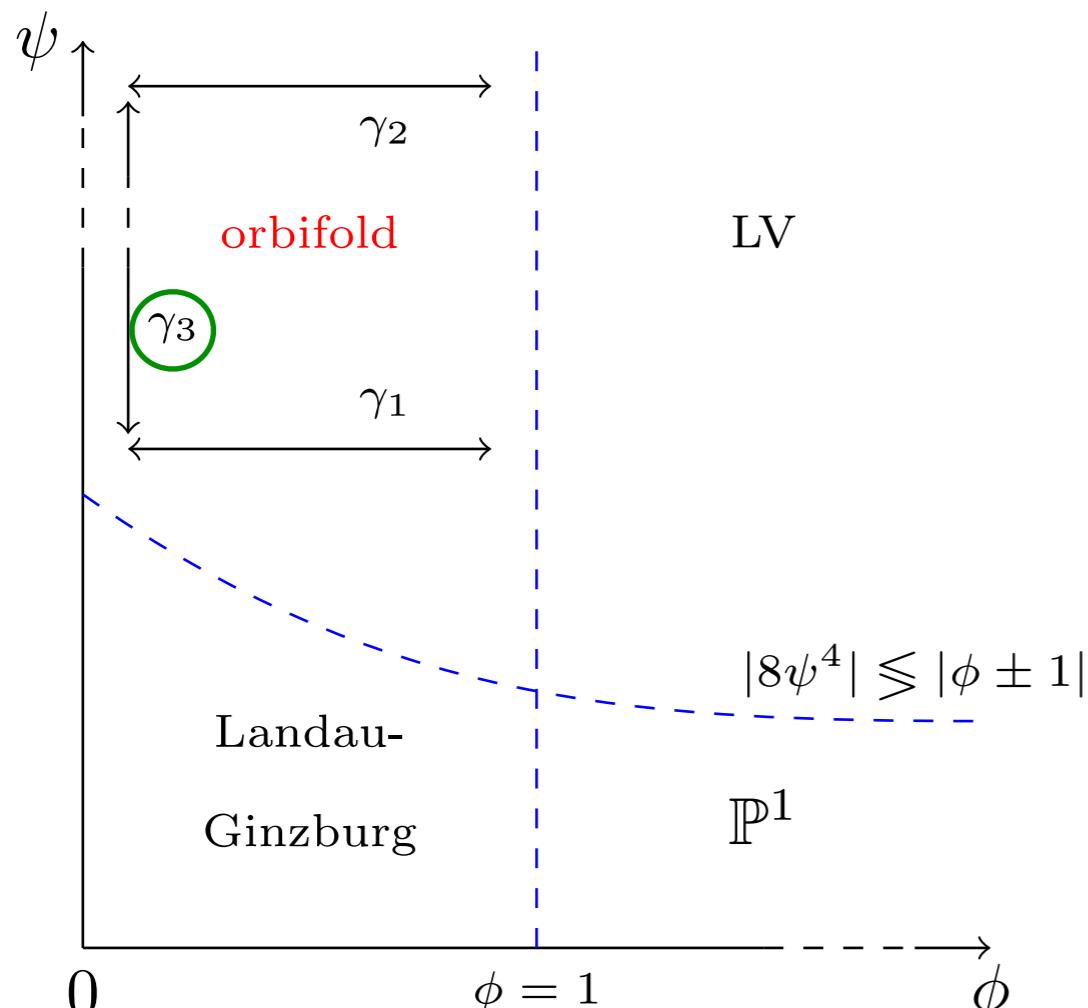
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