

A TWO AXION MODEL OF INFLATION IN SUGRA

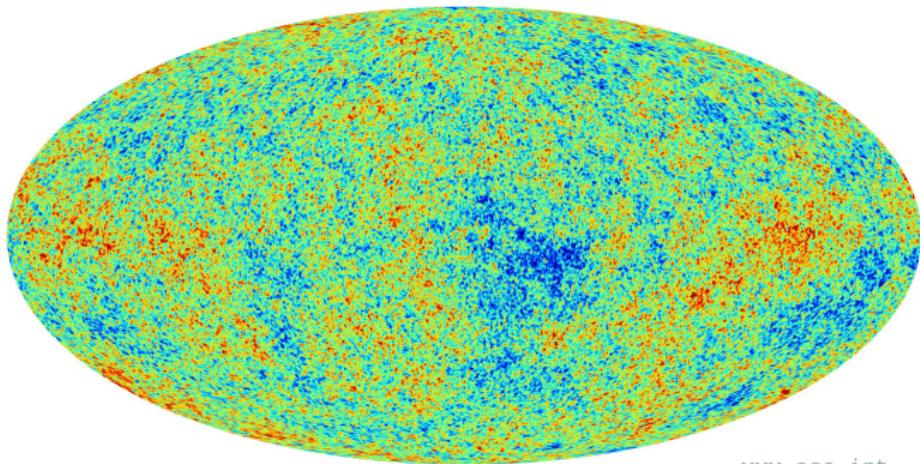
Suvendu Giri



Max-Planck-Institut für Physik, München
IMPRS workshop
June 30, 2015



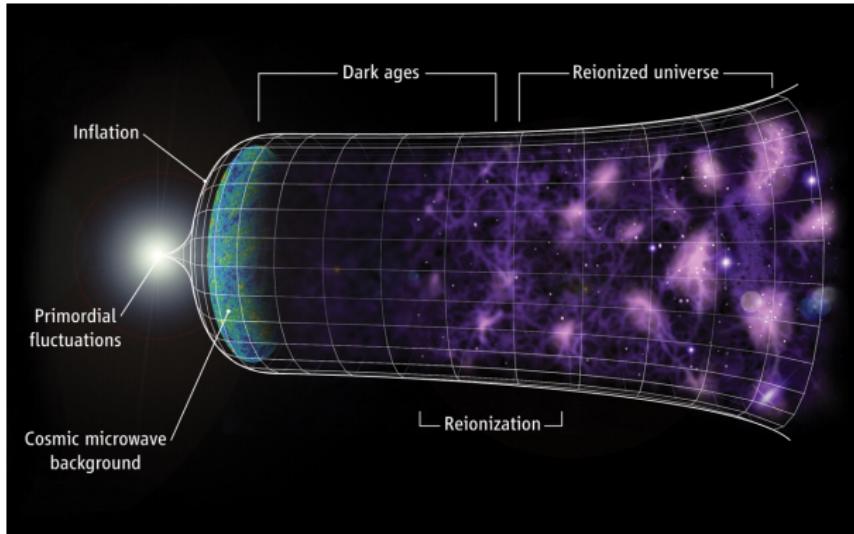
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- ▶ **Horizon problem**
CMB anisotropy $\sim 1 \text{ in } 10^5$
- ▶ **Flatness problem**
 $|1 - \Omega_0^{tot}| \sim 10^{-3}$ (95% CL, CMB+BAO)
- ▶ **Monopole problem**
Monopoles not observed

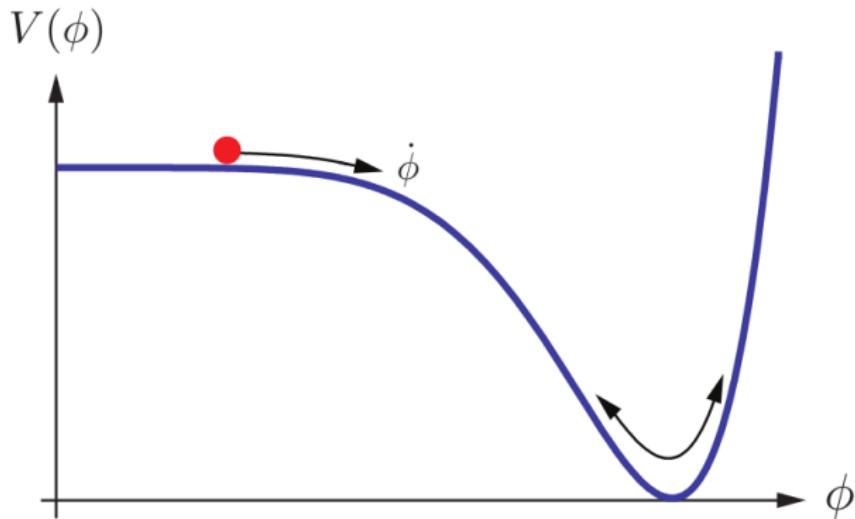
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Faucher-Giguère et al.

- ▶ Rapid expansion from $10^{-36} \sim 10^{-34}$ s
- ▶ Energy of universe dominated by scalar field → Inflaton

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D. Baumann

- ▶ Rapid expansion from $10^{-36} \sim 10^{-34}$ s
- ▶ Energy of universe dominated by scalar field \rightarrow Inflaton
- ▶ Slow roll $\rightarrow \epsilon, \eta$
- ▶ tensor to scalar ratio (r), scalar power spectrum (n_s)

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- ▶ BICEP2 (March 2014) $r \sim 0.2$
- ▶ BICEP2 + PLANCK (February 2015) $r \lesssim 0.12$ (95% CL)
- ▶ BICEP3 ongoing measurements → results expected 2016
- ▶ Measurement of r can narrow down models of inflation

Exciting times for inflationary model building

$$V^{1/4} \simeq \left(\frac{r}{0.01} \right)^{1/4} \cdot 1.06 \cdot 10^{16} \text{ GeV} \quad [\text{Lyth}]$$

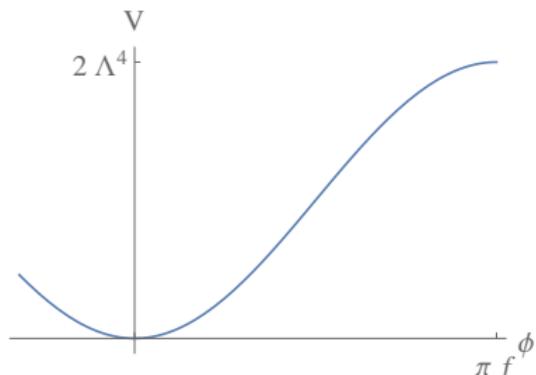
- ▶ Supergravity (SUGRA) → Effective theory of more fundamental UV complete theory (like superstring theory)

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- ▶ Flat potential necessary for slow roll inflation
- ▶ Axions → shift symmetry perturbatively exact, broken by non-perturbative effects

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

- ▶ $r \gtrsim 0.01 \Rightarrow \Delta\phi > M_{Pl}$
(Lyth bound)



- ▶ Flatness of potential threatened by quantum gravity effects
- ▶ Axion shift symmetry protects flatness of potential

Axions one of the most well motivated inflaton candidates

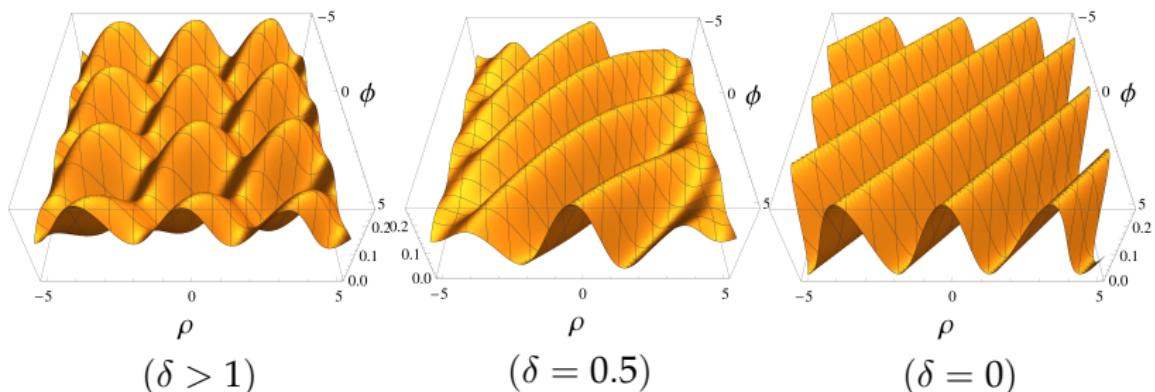
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- String theory : expect $f \lesssim M_S < M_{Pl}$

Axion inflation with one axion problematic → Use two axions !!

$$V = \Lambda^4 \left[1 - \cos \left(\frac{\phi}{f_1} + \frac{\rho}{g_1} \right) \right] + \Lambda^4 \left[1 - \cos \left(\frac{\phi}{f_2} + \frac{\rho}{g_2} \right) \right]$$

KNP alignment mechanism: $\frac{g_2}{g_1} = \frac{f_2}{f_1} (1 + \delta) \Rightarrow f_{\text{eff}} \sim \frac{1}{\delta}$



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$$V = e^K \left[K^{i\bar{j}} D_i W \overline{D_j W} - 3 |W|^2 \right]$$

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$$K = (\Phi_1 + \overline{\Phi}_1)^2 + (\Phi_2 + \overline{\Phi}_2)^2$$

$$W = W_0 + A e^{-p_1 \Phi_1 - p_2 \Phi_2} + B e^{-q_1 \Phi_1 - q_2 \Phi_2}$$

Ben-Dayan, Pedro, Westphal

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where $\Phi_i \equiv \chi_i + i\phi_i$

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where $\Phi_i \equiv \chi_i + i\phi_i$

- ▶ Local SUSY minima $D_i W \stackrel{!}{=} 0 \Rightarrow V < 0 \Rightarrow$ c.c. $< 0 \Rightarrow$ AdS
- ▶ Uplift to dS necessary

CHARACTERIZING THE MODEL

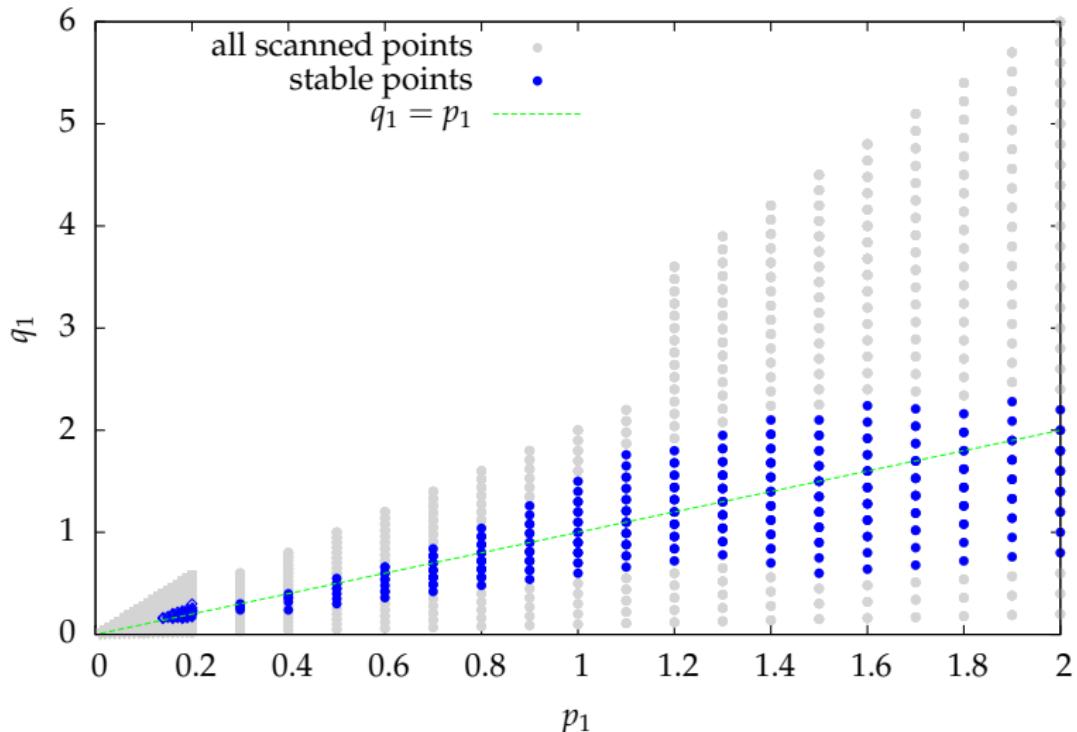
Aligned axion inflation

- ▶ $\Lambda_1, \Lambda_2 > \Lambda_3 \Rightarrow \frac{p_2}{p_1} \sim \frac{q_2}{q_1} \sim \frac{\langle \Phi_1 \rangle}{\langle \Phi_2 \rangle} \Rightarrow$ Aligned axion inflation
- ▶ $W_0 > A, B \Rightarrow$ High scale SUSY breaking
- ▶ but, tachyons ! \rightarrow cure by uplifting

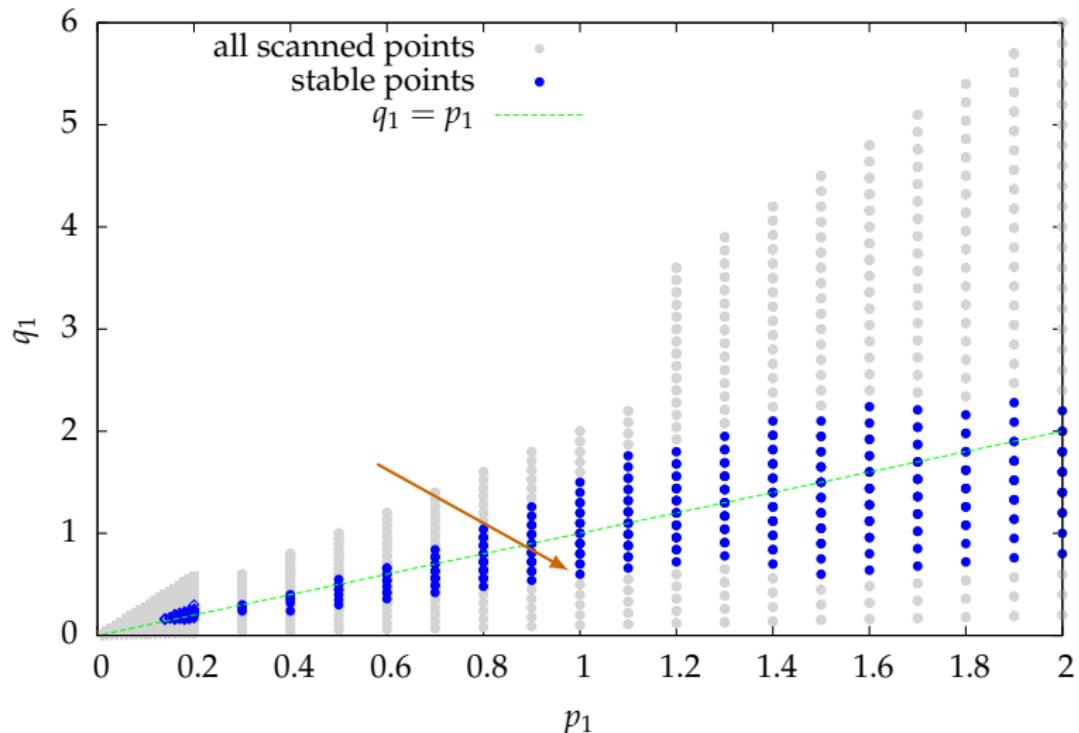
Mixed cosine inflation

- ▶ $\Lambda_1, \Lambda_2 < \Lambda_3 \Rightarrow \frac{p_2}{p_1} \sim \frac{q_2}{q_1} \neq \frac{\langle \Phi_1 \rangle}{\langle \Phi_2 \rangle}$
- ▶ $W_0 < A, B \Rightarrow$ Low scale SUSY breaking
- ▶ parameter scan \rightarrow All fields stabilized at minimum

STABLE PARAMETER RANGES: AN EXAMPLE

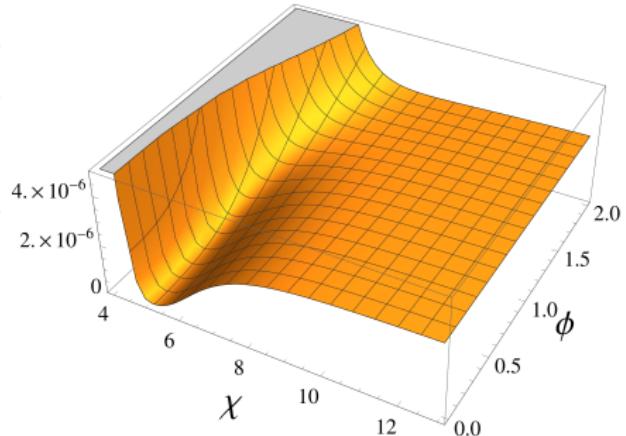


STABLE PARAMETER RANGES: AN EXAMPLE



POTENTIAL AND TRAJECTORY

- ▶ Solve full set of equations of motion for non-canonical kinetic terms
- ▶ e.o.m \rightarrow inflaton trajectory $\rightarrow H \rightarrow$ e-folds
- ▶ Not enough efolds
- ▶ Valley not long enough



$$\ddot{\phi}^i + \Gamma_{jk}^i \dot{\phi}^j \dot{\phi}^k + 3H\dot{\phi}^i + g^{ij} \frac{\partial V}{\partial \phi_j} = 0$$

SUMMARY & OUTLOOK

Summary

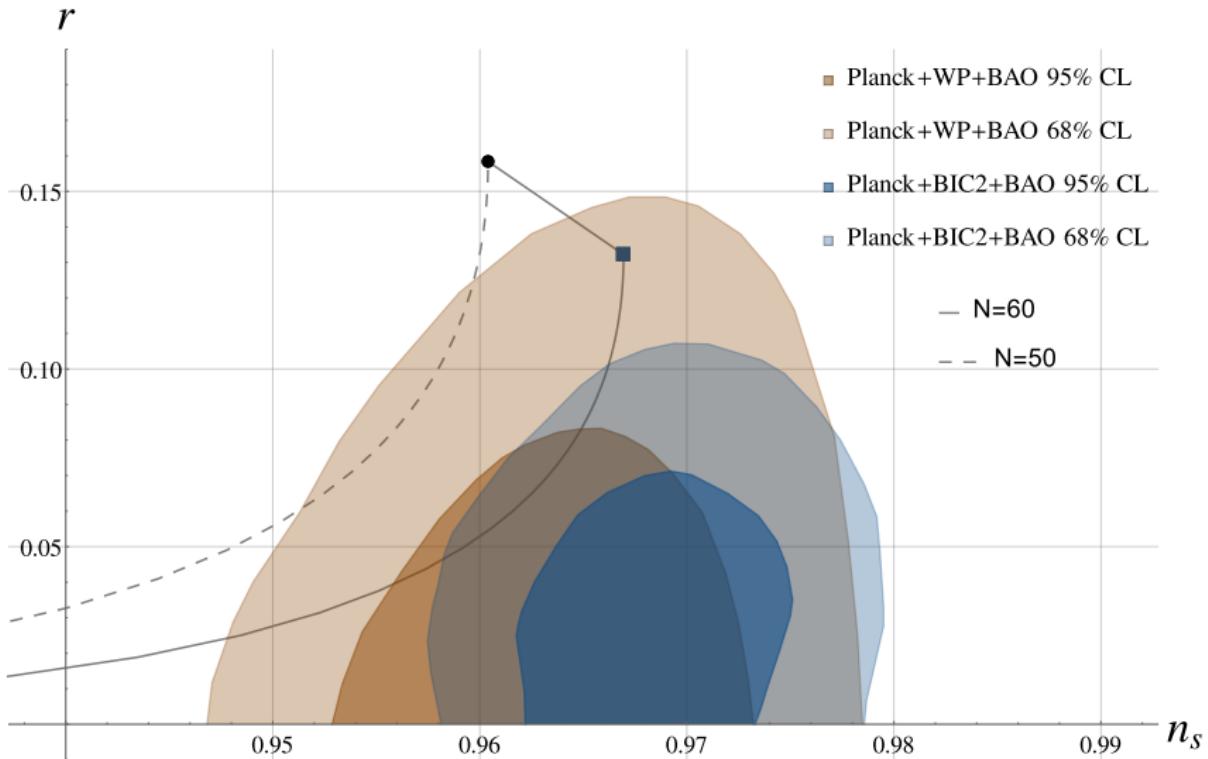
- ▶ Constructed string inspired model of aligned axionic inflation
- ▶ Examined the model in detail
- ▶ Found parameter regions where all fields stabilized at minima
- ▶ Possibility of high and low scale SUSY breaking

Outlook

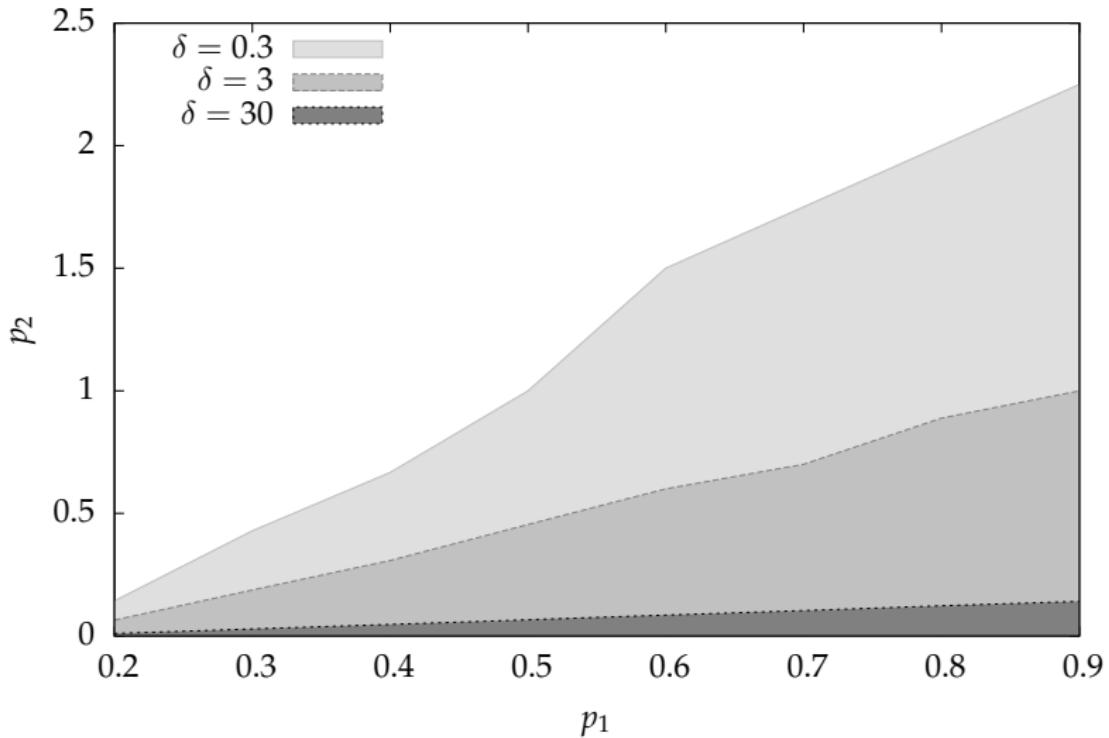
- ▶ Uplifting to end up in dS minima

THANK YOU FOR YOUR ATTENTION

CMB OBSERVABLES

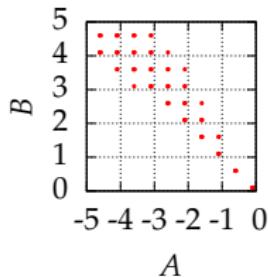


PARAMETER SPACE OF p_1, p_2

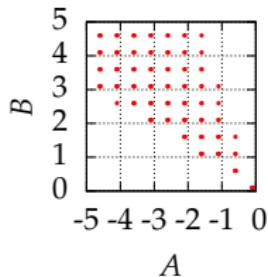


PARAMETER SPACE $A \sim B$

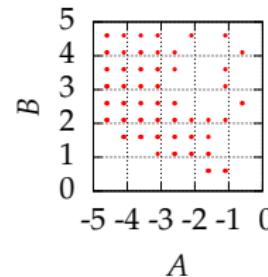
(a)



(b)

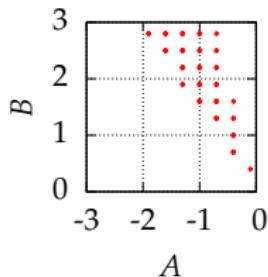


(c)

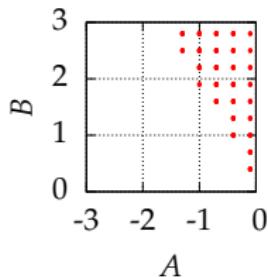


$$\frac{q_1}{p_1} = 0.9$$

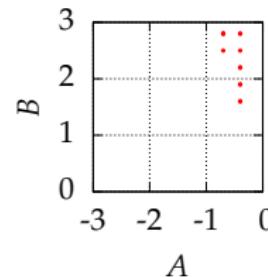
(d)



(e)



(f)



$$\frac{q_1}{p_1} = 1.1$$

→ increasing p_1

MIXED TERM DOMINATION

