Sidetracked Inflation

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Based on **1804.11279** and **1805.12563** with S. Renaux-Petel and J. Ronayne

Destabilizing inflation with heavy fields

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More plausible is that, besides the **inflaton**, other fields were present

- Well motivated theoretically (string theory and supergravity)
- Not problematic — if extra fields were heavy (compared to the Hubble scale H), dynamics can still be effectively single-field

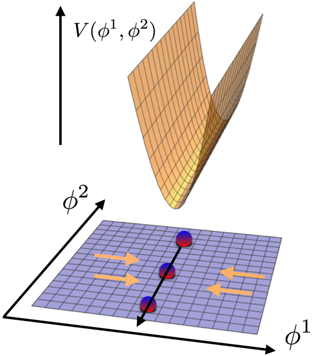

Image credit: S. Renaux-Petel

Destabilizing inflation with heavy fields

But this is still a bit simplistic...

- More generally, higher dimension operators will modify the kinetic structure of the theory

$$-\frac{1}{2}\,\delta_{IJ}\partial^\mu\phi^I\partial_\mu\phi^J \to -\frac{1}{2}\,G_{IJ}(\phi)\partial^\mu\phi^I\partial_\mu\phi^J$$

$\to$ **Curved internal field space**

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- If the field space curvature is $1/M^2$, the scale M need not be too large compared to Hubble

$$H < M < M_{\rm Pl}$$

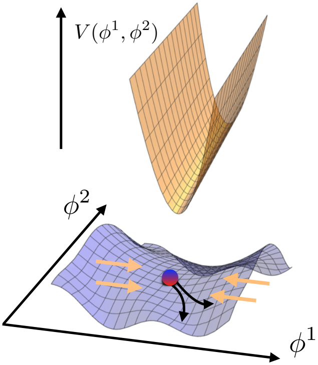

Image credit: S. Renaux-Petel

Destabilizing inflation with heavy fields

$$S = \int d^4x \sqrt{-g} \left[\frac{M_{\rm Pl}^2}{2} R(g) - \frac{1}{2} G_{IJ}(\phi) \partial^\mu \phi^I \partial_\mu \phi^J - V(\phi) \right]$$

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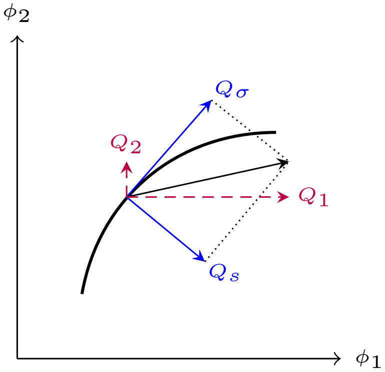
Consider perturbations Q^I (two fields for simplicity), and perform an adiabatic-entropic decomposition

$Q^I \rightarrow$ fluctuation $\delta\phi^I$ in flat gauge

On super-Hubble scales the **entropic mode** satisfies

$$\ddot{Q}_s + 3H\dot{Q}_s + m^2_{s(\rm eff)} Q_s = 0$$



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Crucially, the latter is negative if the internal field space has **negative curvature**

$$\rightarrow \qquad \frac{m^2_{s(\mathrm{eff})}}{H^2} \sim \frac{m_h^2}{H^2} - \epsilon \left(\frac{M_{\mathrm{Pl}}}{M} \right)^2$$

$m_h \rightarrow$ mass of heavy field ($m_h \gg H$)
$M \rightarrow$ curvature scale of internal field space ($M \ll M_{\mathrm{Pl}}$)
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Because ϵ grows during inflation, it is possible that $m^2_{s(\text{eff})}$ becomes negative, even if $m_h^2 \gg H^2$

$\rightarrow$ **Geometrical destabilization of inflation**

Renaux-Petel & Turzynski (2015)

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- Inflation simply ends

  → **“premature end of inflation”**

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Two possible outcomes

- Inflation simply ends

  $\rightarrow$ **"premature end of inflation"**

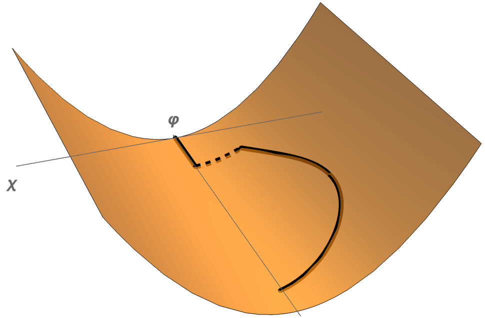
  Renaux-Petel, Turzynski, Vennin (2017)

- A second phase of inflation begins

  $\rightarrow$ **"sidetracked inflation"**

  SGS, Renaux-Petel, Ronayne (2018)

Sidetracked inflation



- The instability causes the inflationary trajectory to divert from its original path in field space

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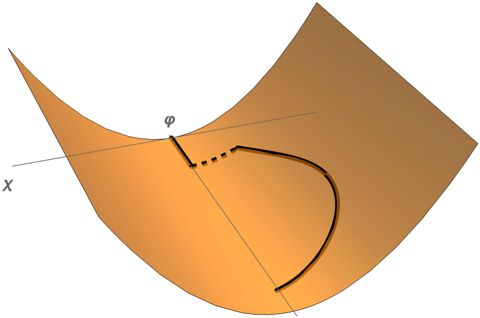

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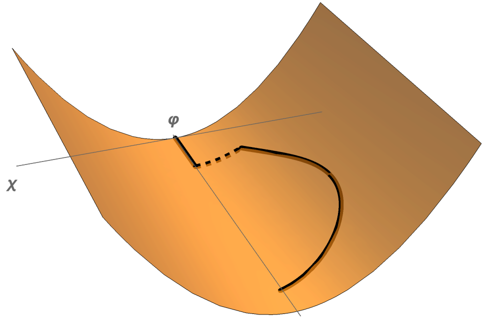

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- This is possible because of the existence of an **attractor solution** away from the minimum of the potential (in a broad class of models)
- Observed before in specific models (hyperinflation, angular inflation) but in fact much more generic   See E. Sfakianakis' talk

Sidetracked inflation

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Main results:

- Numerical calculation of power spectrum and non-Gaussianities in several models — large differences compared to single-field expectations
- Analytical approximations for background dynamics
- Derivation of an **effective single-field theory** of perturbations — fluctuations propagate with an effective dispersion relation which can be:

  Non-relativistic: $\omega^2 = c_s^2 k^2$ with $c_s \ll 1$

  Non-linear: $\omega^2 \propto k^4$

  With imaginary speed of sound: $\omega^2 = c_s^2 k^2$ with $c_s^2 < 0$

Sidetracked inflation

Our models:

$$S = \int d^4x \sqrt{-g} \left[\frac{M_{\rm Pl}^2}{2} R(g) - \frac{1}{2} G_{IJ}(\phi) \partial^\mu \phi^I \partial_\mu \phi^J - V(\phi) \right]$$

with $\phi^I = (\varphi, \chi)$

$$V(\phi) = \Lambda^4 \mathcal{V}(\varphi) + \frac{1}{2} m_h^2 \chi^2$$

$\mathcal{V}(\varphi) \to$ dimensionless inflaton potential

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We considered two field space metrics

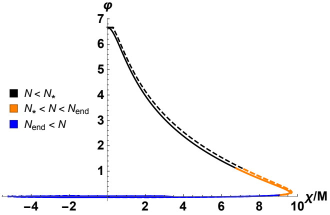
- Minimal:

$$G_{IJ} d\phi^I d\phi^J = \left(1 + \frac{2\chi^2}{M^2}\right) d\varphi^2 + d\chi^2$$

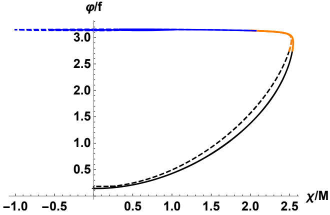
- Hyperbolic:

$$G_{IJ} d\phi^I d\phi^J = \left(1 + \frac{2\chi^2}{M^2}\right) d\varphi^2 + \frac{2\sqrt{2}\,\chi}{M} d\varphi d\chi + d\chi^2$$

Sidetracked inflation



Starobinsky inflation
$\mathcal{V} = \left(1 - e^{\sqrt{2/3}\,\varphi}\right)^2$



Natural inflation $\mathcal{V} = 1 + \cos\left(\varphi/f\right)$

Minimal metric $\rightarrow$ solid line
Hyperbolic metric $\rightarrow$ dashed line

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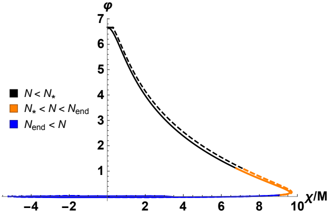

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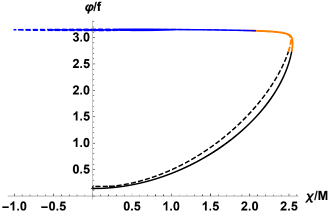

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Remarks

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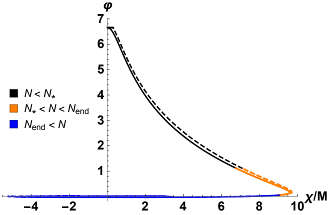

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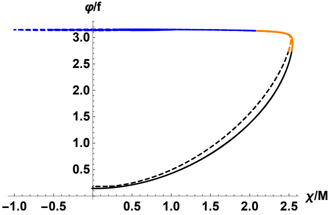

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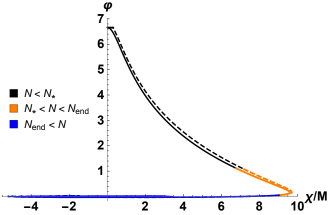

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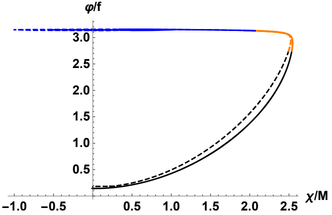

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- Very non-geodesic trajectories: $\eta_\perp \equiv -V_s/(H\dot{\sigma}) \gg 1$
- Super-Hubble entropic mass $m^2_{s(\mathrm{eff})}$ very large — decay of entropic modes and conservation of ζ

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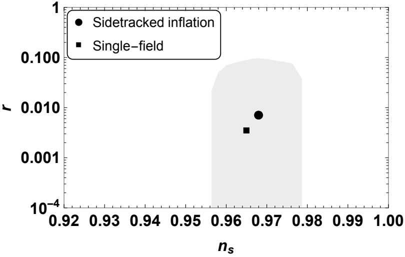

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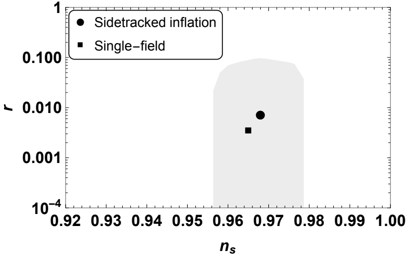

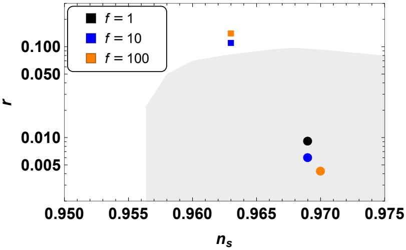

Minimal metric, Starobinsky inflation $\mathcal{V} = \left(1 - e^{\sqrt{2/3}\,\varphi}\right)^2$

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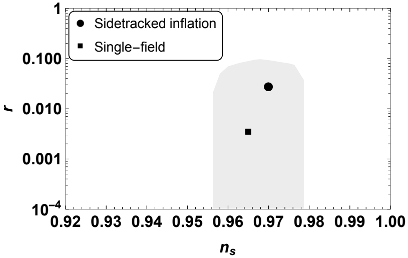
$r \to$ tensor-to-scalar ratio

$n_s \to$ spectral index

Sidetracked inflation



Hyperbolic metric, Starobinsky inflation $\mathcal{V} = \left(1 - e^{\sqrt{2/3}\,\varphi}\right)^2$

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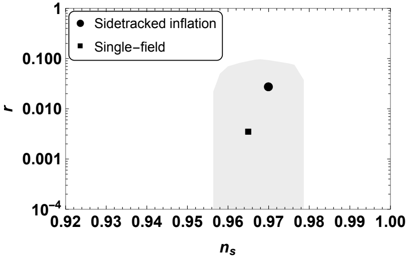

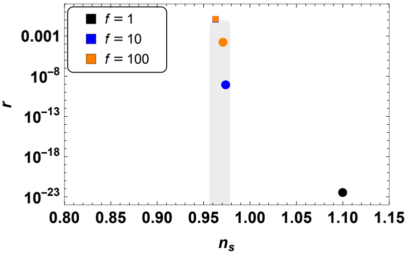

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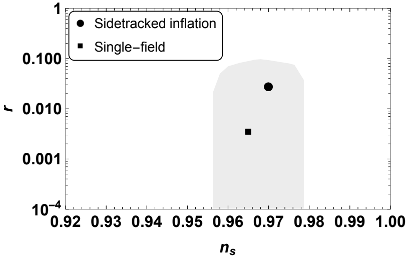

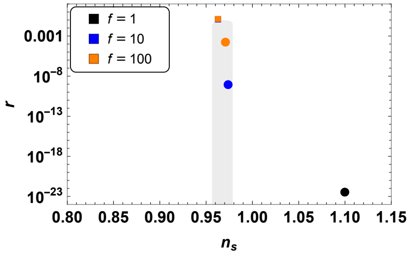

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Remark

- Suppression of r in natural inflation due to tachyonic instability — $c_s^2 < 0$ in EFT description

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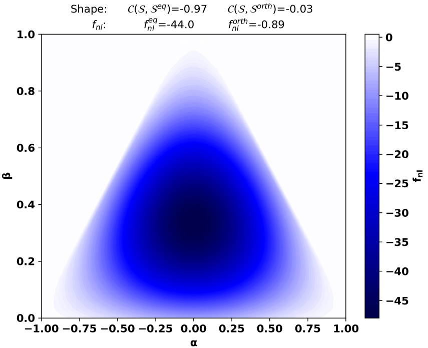
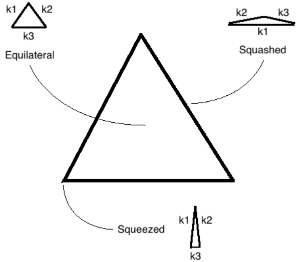


Minimal metric, Natural inflation
$(f = 10)$



- Size of non-Gaussianities — quantified by f_{nl}
- Shape of non-Gaussianities — quantified by correlation $\mathcal{C}$ with a given template

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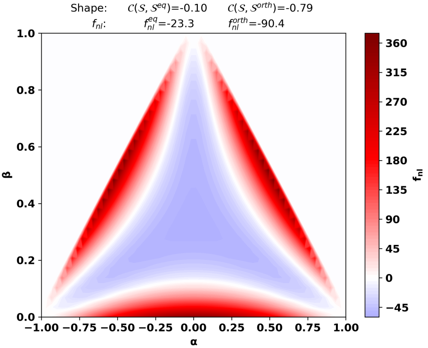

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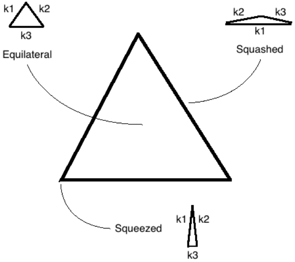

- Sidetracked inflation predicts large non-Gaussianities and allows for a non-standard “orthogonal shape” in the hyperbolic case

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