THE OBSERVATIONAL POSITION OF SIMPLE NON-MINIMALLY COUPLED INFLATIONARY SCENARIOS

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Edwards and Liddle; June 2014; arXiv:**1406.5768**[astro-ph.CO]

Kallosh, Linde and Roest; Oct. 2013; arXiv:**1310.3950**[hep-th]

Kehagias, Dizgah and Riotto; Dec. 2013; arXiv:**1312.1155** [hep-th]

Kallosh and Linde; Sep. 2013; arXiv:**1309.2015**[astro-ph.CO]

THE UNIVERSAL ATTRACTORS

Kallosh, Linde and Roest; Oct. 2013; arXiv:1310.3950[hep-th]

The Jordan Frame:

$$\mathscr{L}_J = \sqrt{-g}\left[\frac{1}{2}\Omega(\phi)R - \frac{1}{2}(\partial\phi)^2 - V_J(\phi)\right]$$

$$\Omega(\phi) = 1 + \xi f(\phi) \quad ; \quad V_{\rm J}(\phi) = \lambda^2 f^2(\phi)$$

Transformation to the Einstein Frame:

$$g_{\mu\nu} \to \Omega^{-1}(\phi) g_{\mu\nu}$$

$$\mathscr{L}_{\rm E} = \sqrt{-g}\left[\frac{1}{2}R - \frac{1}{2\Omega^2(\phi)}\left(\Omega(\phi) + \frac{3}{2}\left[\frac{d\Omega(\phi)}{d\phi}\right]^2\right)(\partial\phi)^2 - \frac{V_{\rm J}(\phi)}{\Omega^2(\phi)}\right]$$

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A journey to observable quantities:

$$\left[\frac{\partial\varphi}{\partial\phi}\right]^2 = \frac{1}{\Omega^2(\phi)}\left(\Omega(\phi) + \frac{3}{2}\left[\frac{d\Omega(\phi)}{d\phi}\right]^2\right)$$

$$\epsilon \equiv \frac{\Omega^4(\phi)}{V_{\mathrm{J}}^2(\phi)}\left(\frac{d}{d\phi}\left[\frac{V_{\mathrm{J}}(\phi)}{\Omega^2(\phi)}\right]\right)^2\left(\frac{\partial\phi}{\partial\varphi}\right)^2$$

$$\eta = 2\epsilon + \frac{\partial\epsilon}{\partial\varphi}\frac{1}{\sqrt{2\epsilon}}$$

These take on a form independent of the potential in the "strong coupling" limit

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Evaluate number of e-foldings:

$$N = \int \frac{1}{\sqrt{2\epsilon}} d\varphi = \frac{1}{4} \int \frac{f(\phi)}{f'(\phi)} \frac{2 + 2\xi f(\phi) + 3[\xi f'(\phi)]^2}{1 + \xi f(\phi)} d\phi$$

$$\xi f(\phi) \gg 1$$

$$N \simeq \frac{3}{4} \xi f(\phi_N) .$$

Apply to the expressions for the slow-roll parameters:

$$r = \frac{12}{N^2}$$

$$n_s = 1 - \frac{2}{N}$$

THE UNIVERSAL ATTRACTORS

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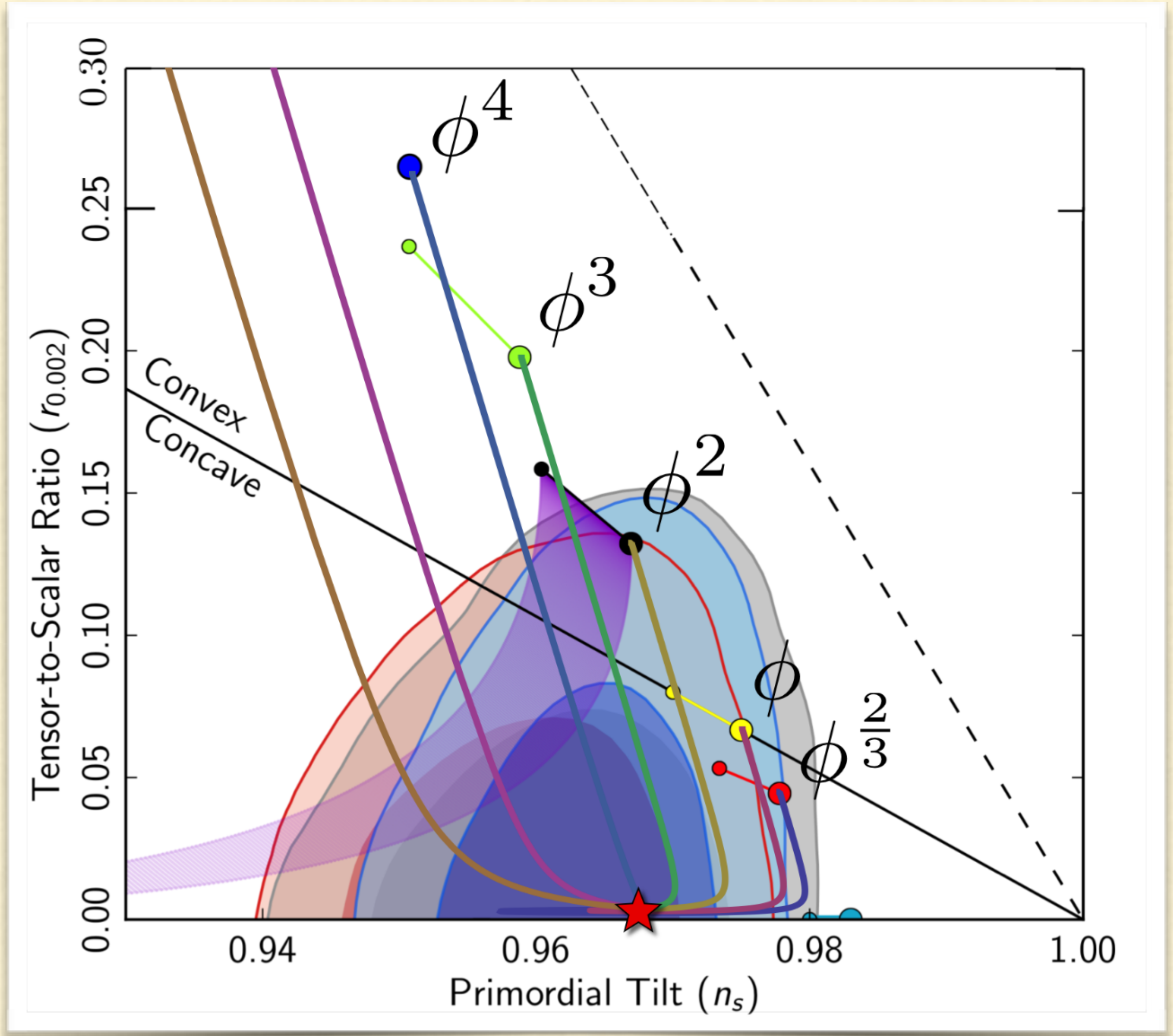

THE UNIVERSAL ATTRACTORS?

Kallosh, Linde and Roest; Oct. 2013; arXiv:1310.3950[hep-th]   Edwards and Liddle; June 2014; arXiv:1406.5768[astro-ph.CO]

Re-evaluate number of e-foldings:

$$\xi f(\phi) \gg 1$$

$$N \simeq \frac{3}{4}\xi f(\phi_N) .$$

$$N = \frac{3}{4}\xi f(\phi_N) - \frac{3}{4}\log\frac{f(\phi_N)}{f(\phi_{\rm end})}$$

Apply to the expressions for the slow-roll parameters:

$$\delta r = -\frac{24\delta N}{N^3} = -\frac{12}{N}\delta n_{\rm s}$$

THE UNIVERSAL ATTRACTORS?

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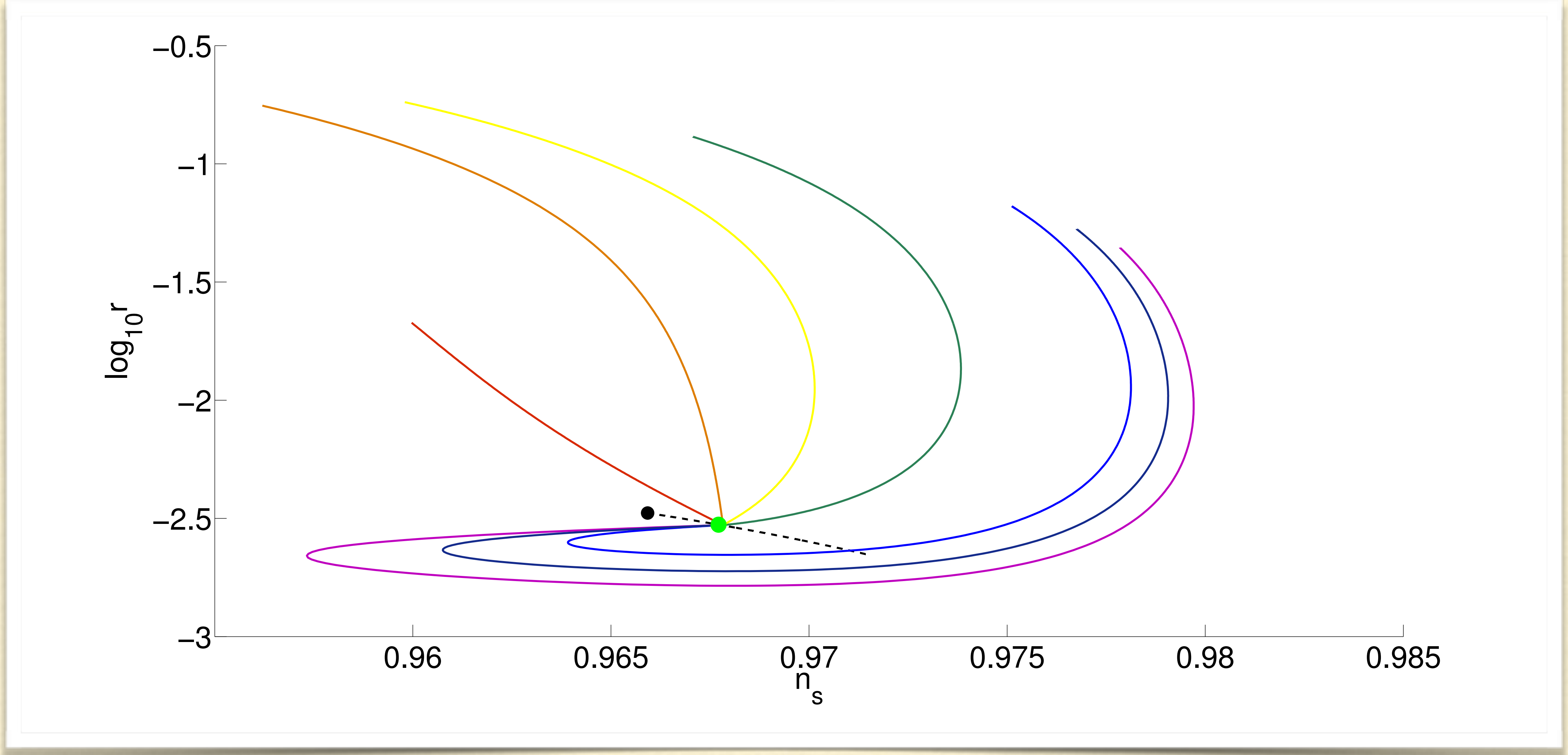


APPROACHING THE ATTRACTOR

Edwards and Liddle; June 2014; arXiv:1406.5768[astro-ph.CO]

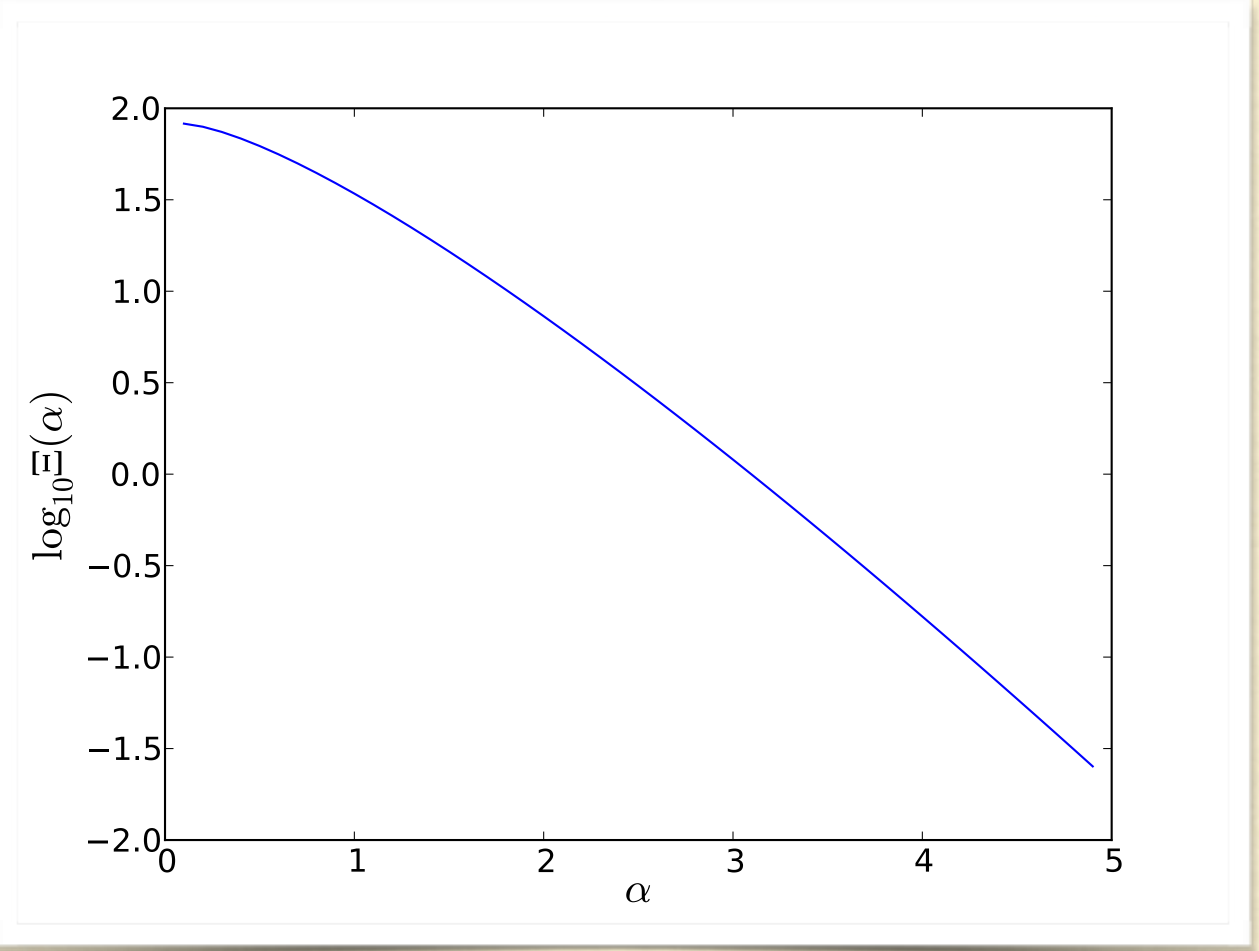
Once a form for the potential is specified, it is possible to quantify where Universal Attractor regime is approached:

$$3\left[\xi f'(\phi)\right]^2 > 2\xi f(\phi)$$

Two specific cases considered:

$$f(\phi) = \phi^{\alpha/2}$$

$$\Xi(\alpha) \equiv \left(\frac{8}{3\alpha^2}\right)^{\alpha/4}\left(\frac{4N}{3}\right)^{1-\alpha/4}$$



APPROACHING THE ATTRACTOR

Edwards and Liddle; June 2014; arXiv:1406.5768[astro-ph.CO]

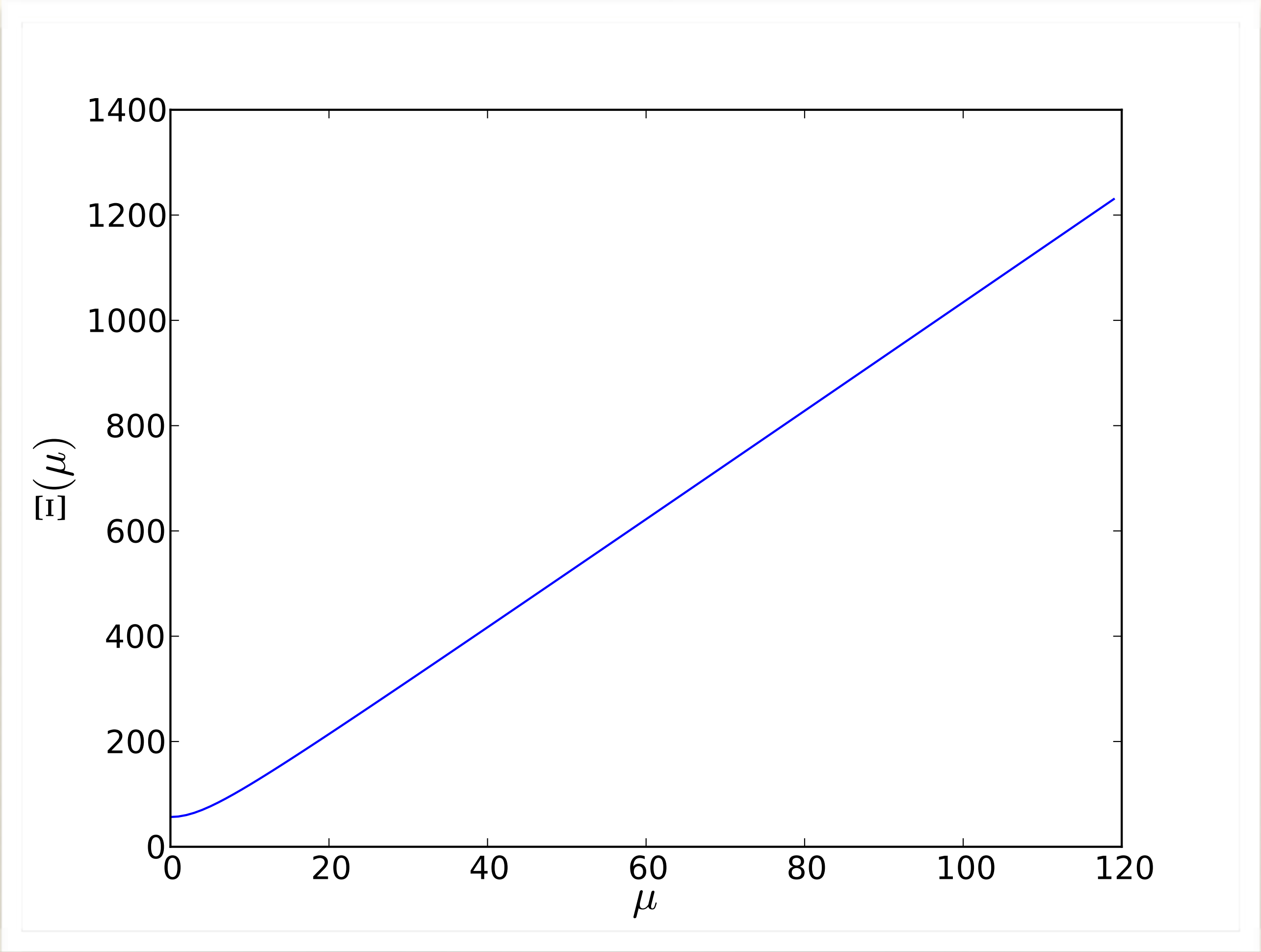
Once a form for the potential is specified, it is possible to quantify where Universal Attractor regime is approached:

$$3\left[\xi f'(\phi)\right]^2 > 2\xi f(\phi)$$

Two specific cases considered:

$$f(\phi) = \sqrt{1+\cos(\phi/\mu)}$$

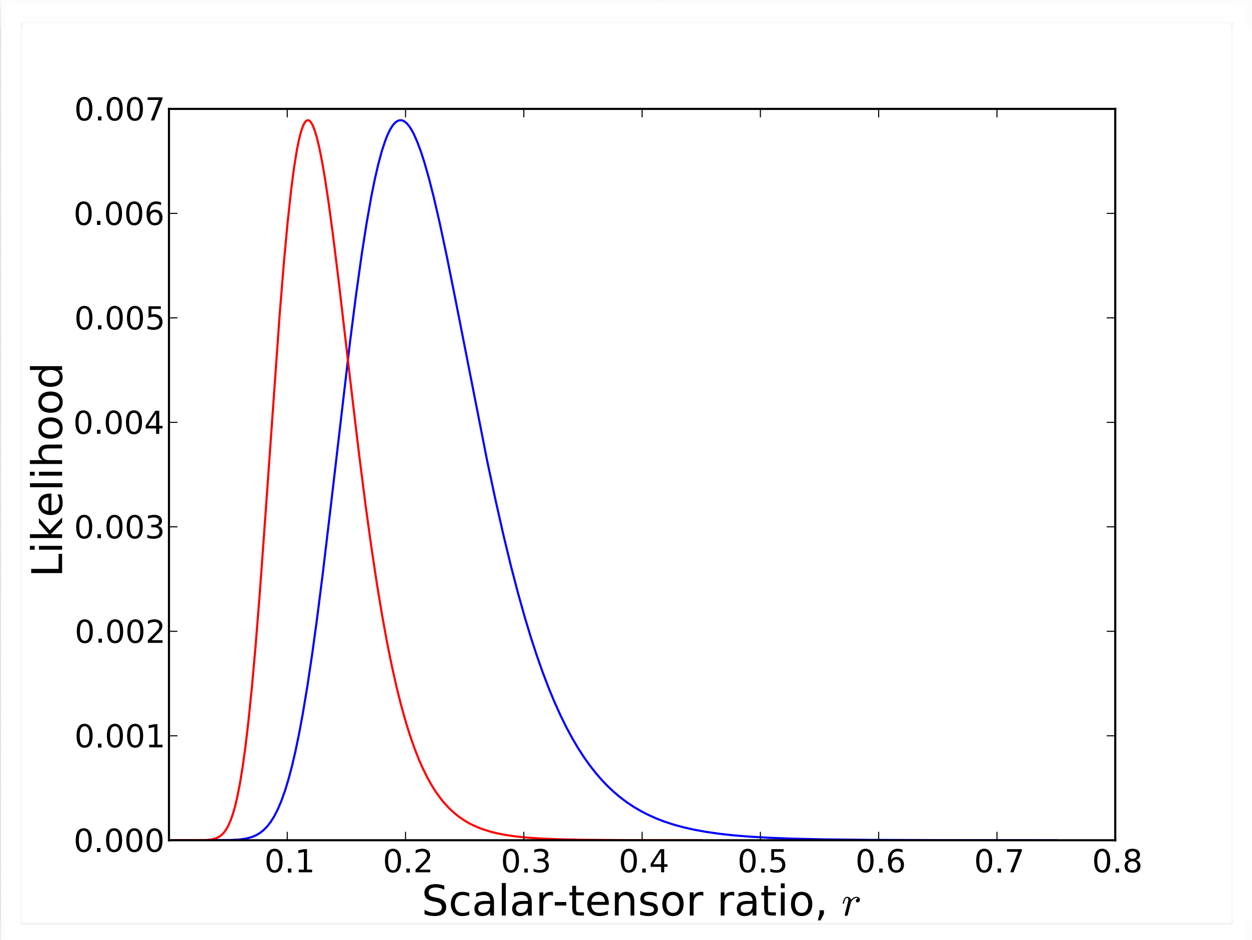
$$\Xi(\mu) \equiv \frac{4}{3}\sqrt{\frac{N^2}{2} + N\mu^2}$$

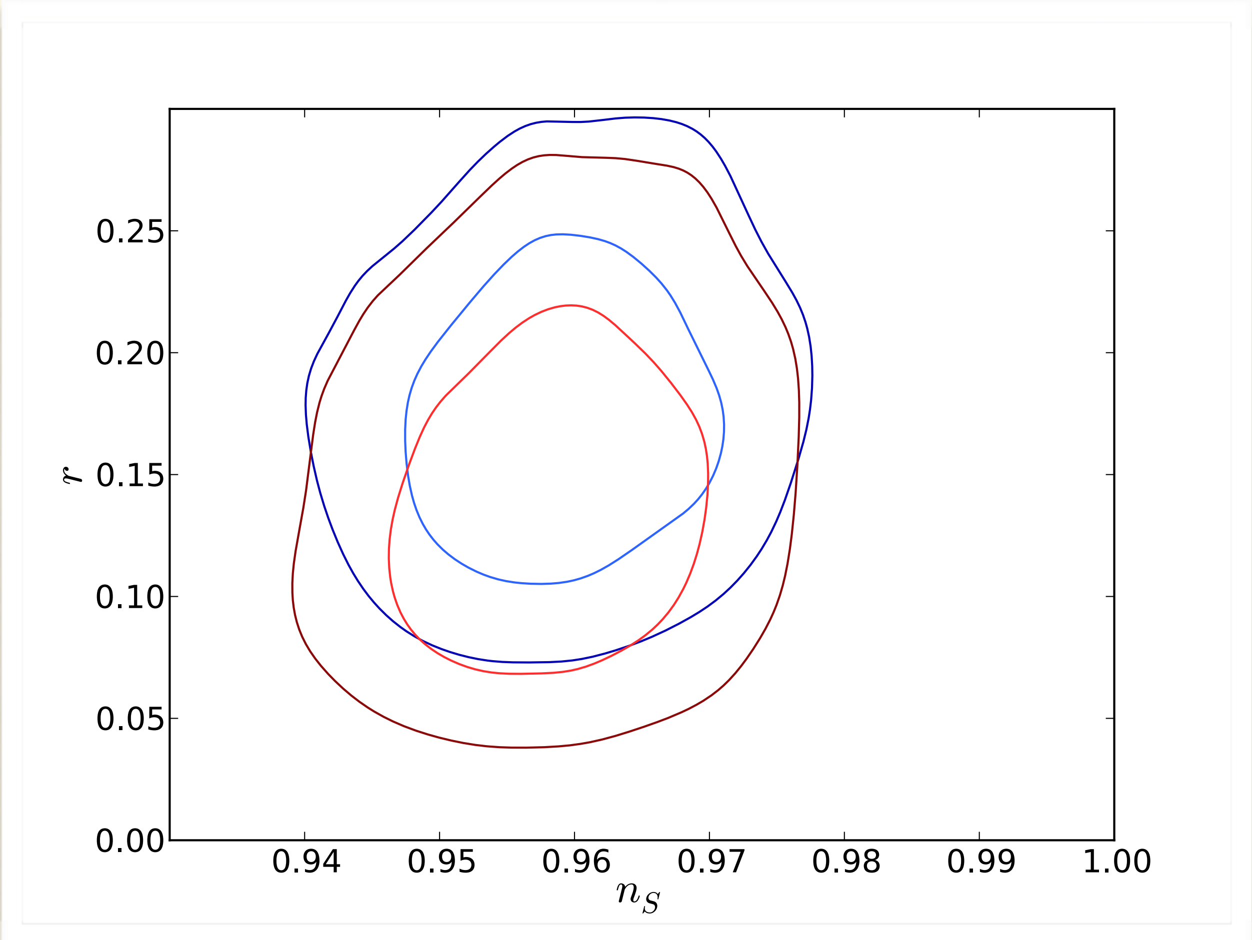


OBSERVATIONAL CONSTRAINTS

Edwards and Liddle; June 2014; arXiv:1406.5768[astro-ph.CO]

The Universal Attractors give $r \sim 0.005$, but what if we manage to put a lower bound on r greater than this value?





2013 Planck Collaboration Data Release and BICEP "inspired"

OBSERVATIONAL CONSTRAINTS

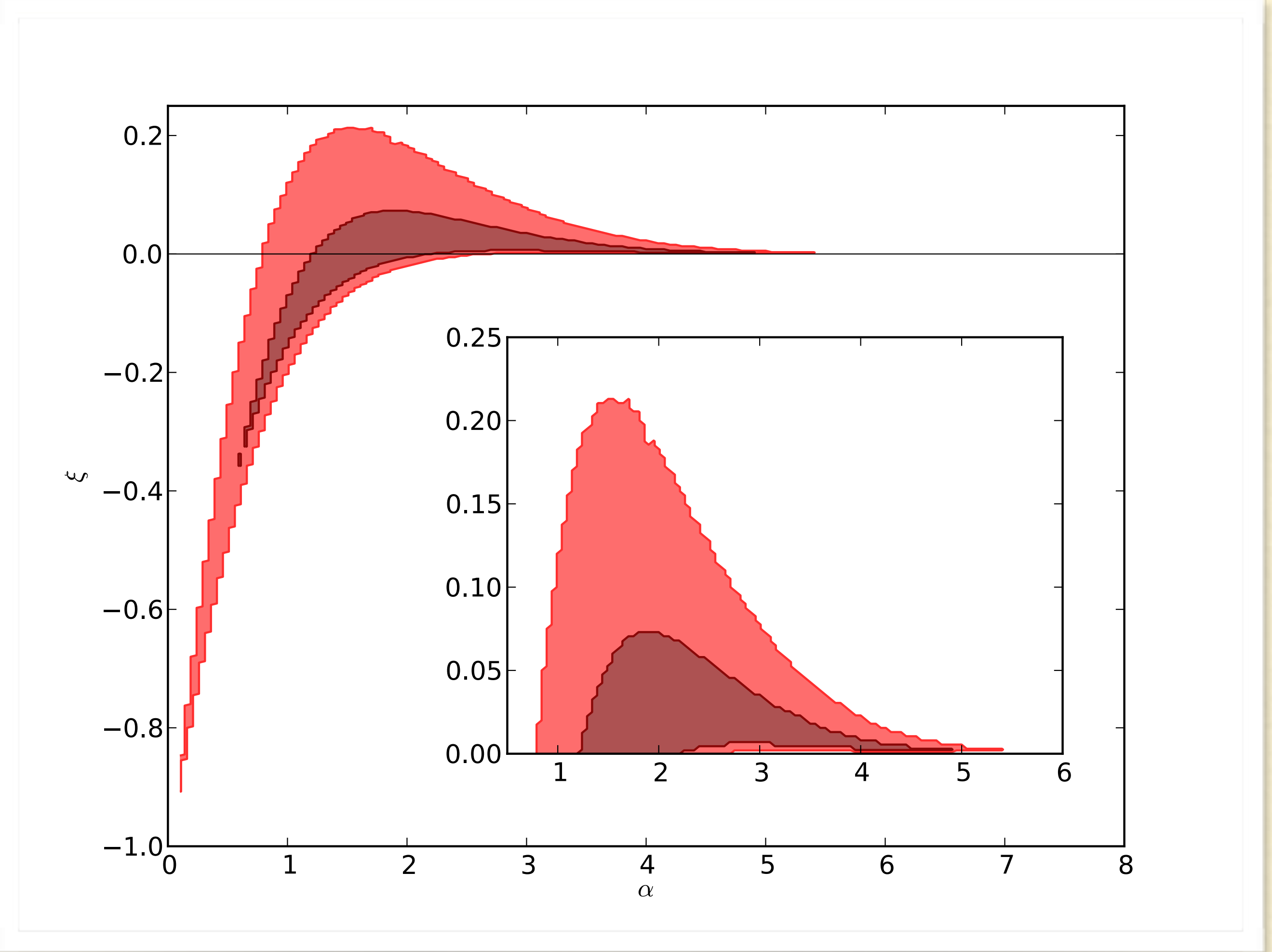
Edwards and Liddle; June 2014; arXiv:1406.5768[astro-ph.CO]

The more optimistic case, $r > 0.05$

Form of potential and coupling:

$$f(\phi) = \phi^{\alpha/2}$$

$$\Omega(\phi) = 1 + \xi f(\phi)$$



OBSERVATIONAL CONSTRAINTS

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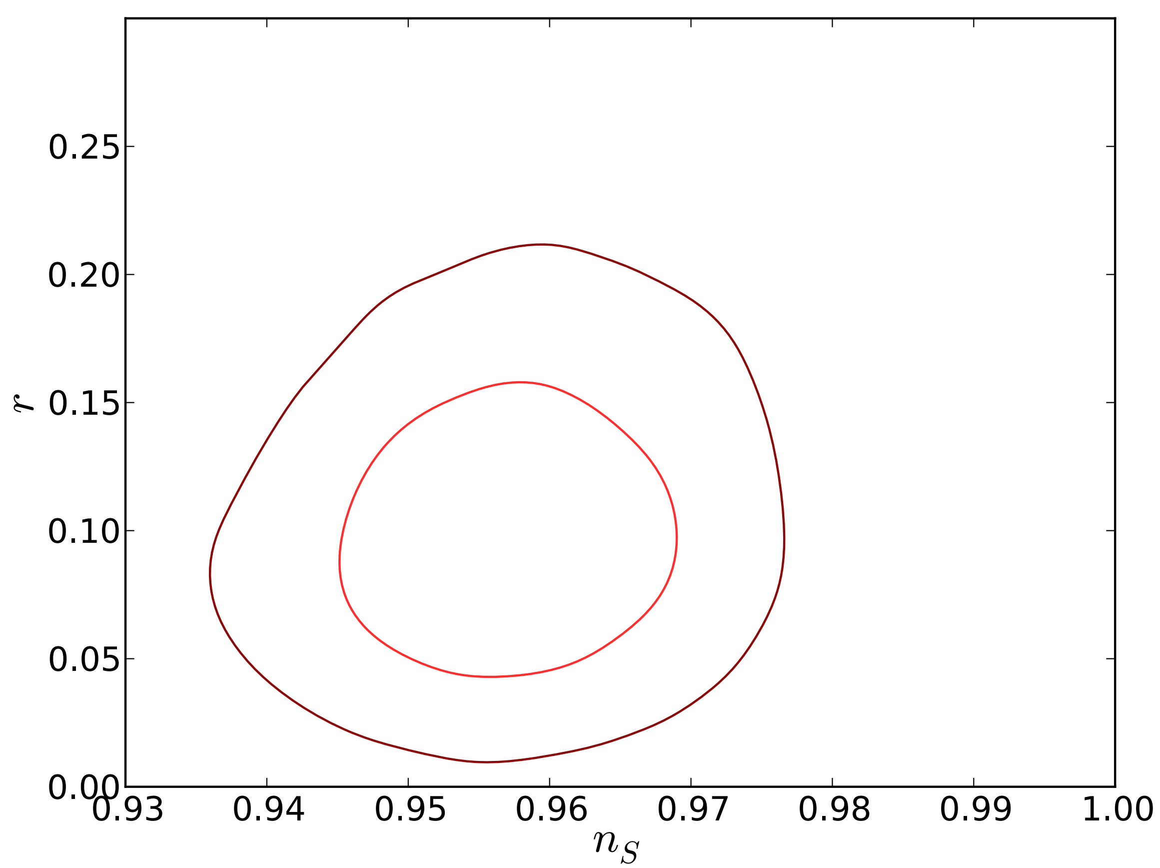
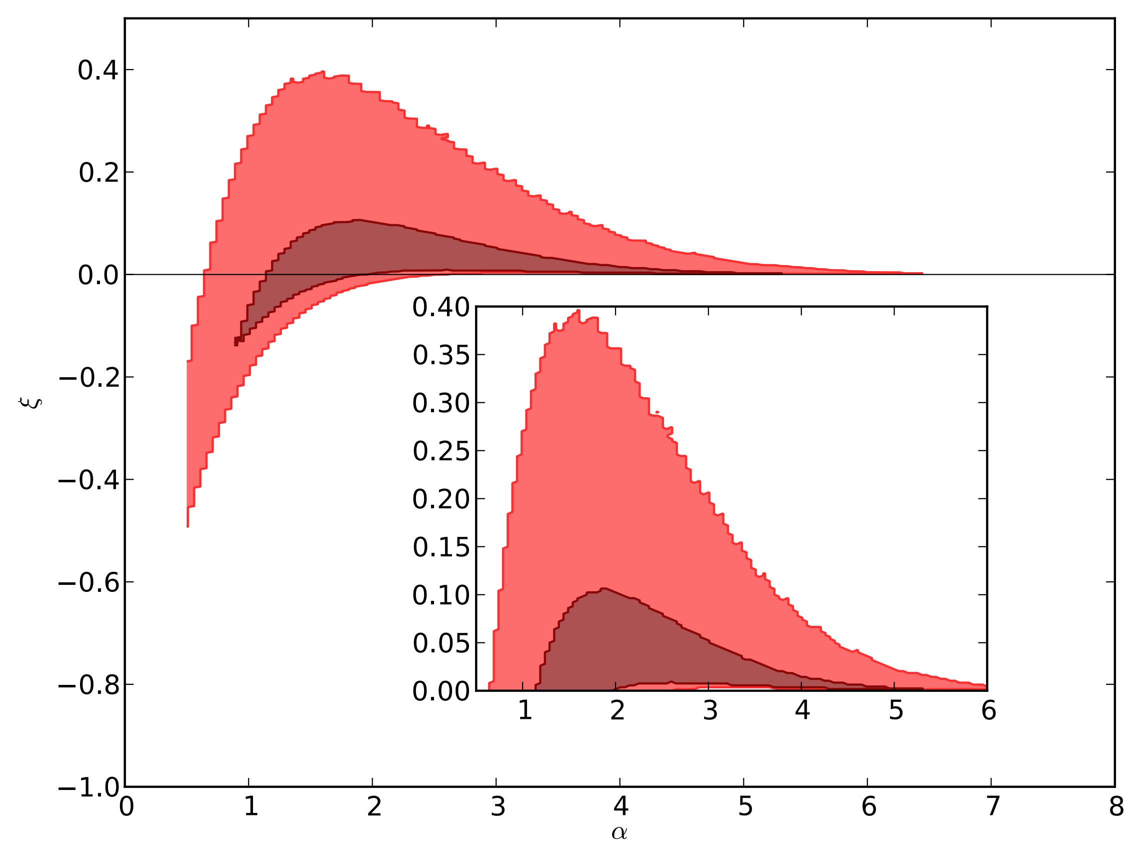
The less optimistic case, $r > 0.01$





THE NEXT STEP - MORE FIELDS

Kallosh and Linde; September 2013; arXiv:1309.2015[astro-ph.CO]

Starting point:

$$\mathcal{L} = \sqrt{-g}\left[\frac{1}{2}\left((\partial_\mu \chi)^2 - \sum_i (\partial_\mu \phi_i)^2\right) + \frac{\chi^2 - \sum_i {\phi_i}^2}{12} R - \frac{F\left(\frac{\phi_i}{\chi}\right)}{36}\left(\chi^2 - \sum_i {\phi_i}^2\right)^2\right]$$

Break the conformal symmetry:

$$\mathcal{L} = \sqrt{-g}\left[-\sum_i (\partial_\mu \phi_i)^2 + \frac{1}{2} R - \frac{\sum_i {\phi_i}^2}{12} R - \frac{F\left(\frac{\phi_i}{\sqrt{6}}\right)}{36}\left(6 - \sum_i {\phi_i}^2\right)^2\right]$$

Now analyse this using transport code of Dias, Frazer and Seery; Feb 2015; arXiv:1502.03125[astro-ph.CO]

THE NEXT STEP - MORE FIELDS

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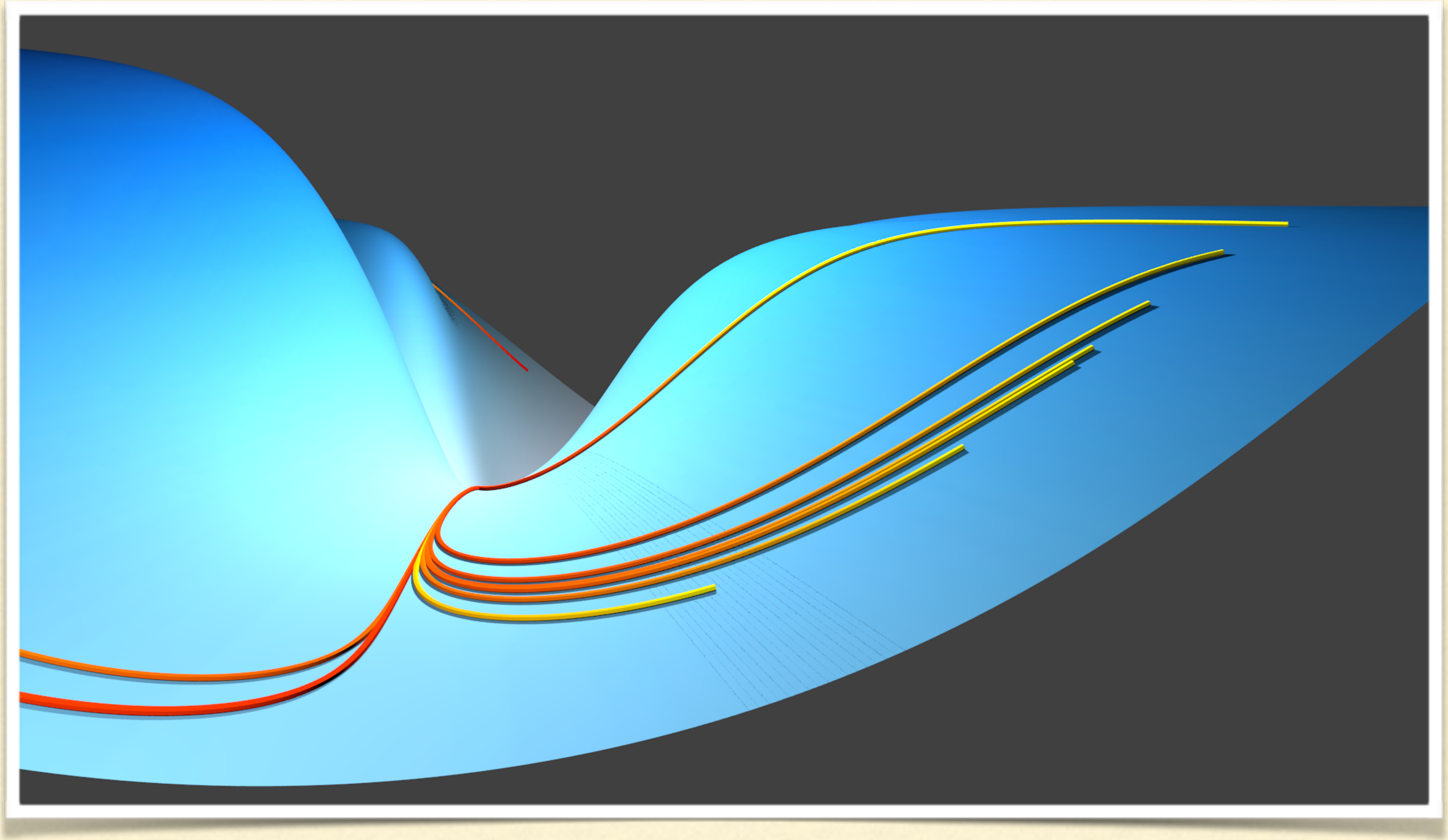

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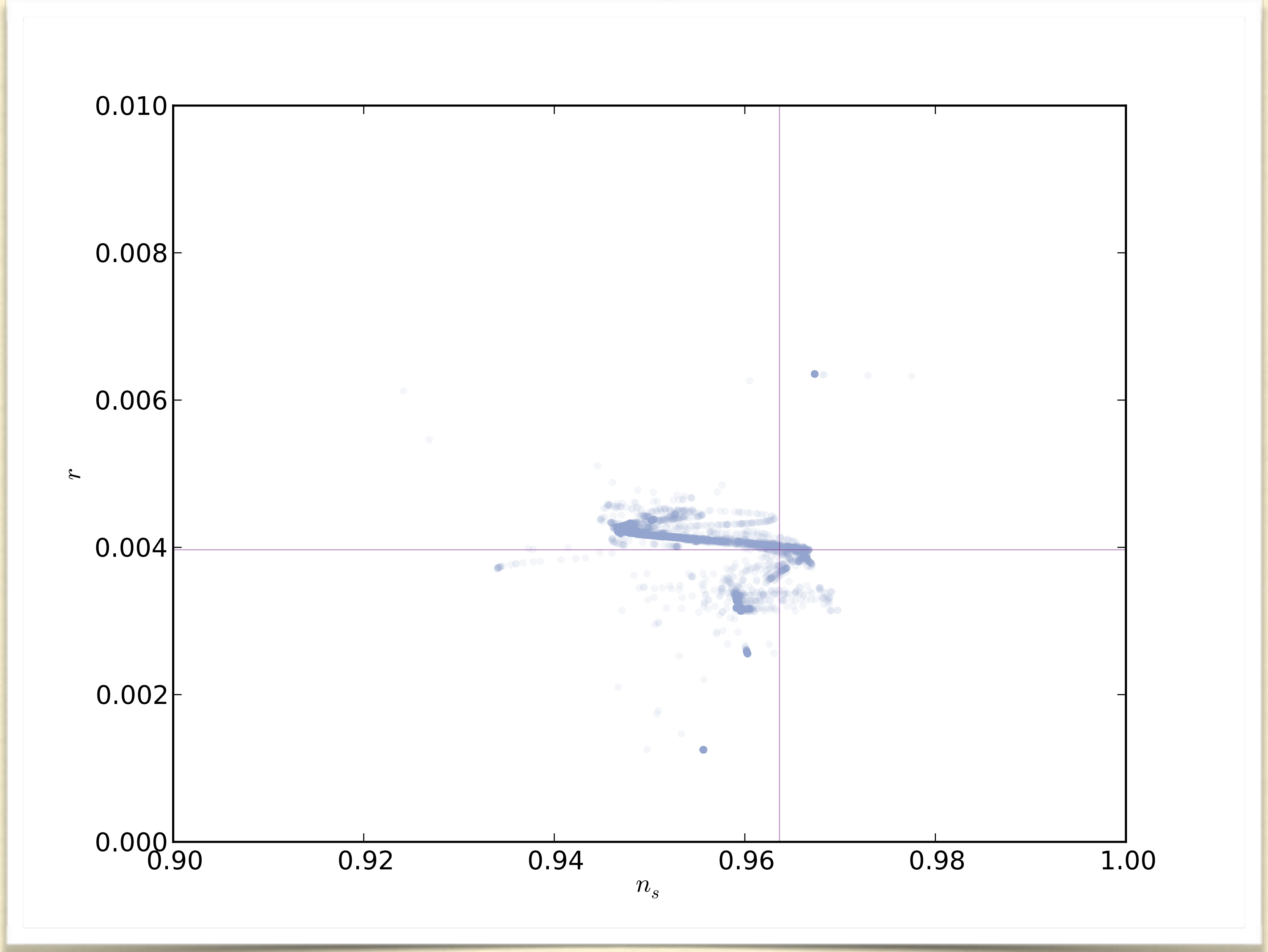

CONCLUSION

- The Universal Attractors do have a universal prediction.
    - But it is **not** the same as predicted by the Starobinsky model (close though!)

- A measurement of non-zero *r* would allow fairly tight constraints on the coupling parameter.

- Wide range of phenomenon to understand in the 2-D case.