SINGLE-FIELD INFLATION MODELS IN SUPERGRAVITY

- $f(R)$ GRAVITY AS GRAVITY + SCALAR
- THE "STAROBINSKY" CASE $f = R + \alpha R^2$
- R^n CORRECTIONS
- $R + \alpha R^2$ SUPERGRAVITY AT LINEAR ORDER
- THE NEW MINIMAL SUPERGRAVITY
- NEW MINIMAL COMPLETION OF $R + \alpha R^2$ GRAVITY
- HIGHER-CURVATURE CORRECTIONS
- NEW MINIMAL CHAOTIC INFLATION AND F TERMS

BOSONIC HIGHER-CURVATURE GRAVITY

SET $8\pi G = 1$

EINSTEIN ACTION PLUS HIGHER-CURVATURE CORRECTIONS

$$L = \frac{1}{2}R + f(R) = \frac{1}{2}R + f(X) + \frac{1}{2}Y(R - X)$$

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RESCALE TO EINSTEIN FRAME

$$g_{mn} \to (1+Y)^{-1} g_{mn}$$

$$(1+Y)\sqrt{-g}R \to \sqrt{-g}R - \frac{3}{2}\sqrt{-g}[\partial_m \log(1+Y)]^2$$

THE LAGRANGIAN DENSITY BECOMES

$$L = \frac{1}{2}R - \frac{1}{2}(\partial_m \phi)^2 - (1+Y)^{-2}\tilde{f}[Y(\phi)]$$

$$\phi = \sqrt{3/2}\log(1+Y)$$

$$\tilde{f}(Y) = YX - f(X)|_{f'(X)=Y}$$

LEGENDRE TRANSFORM

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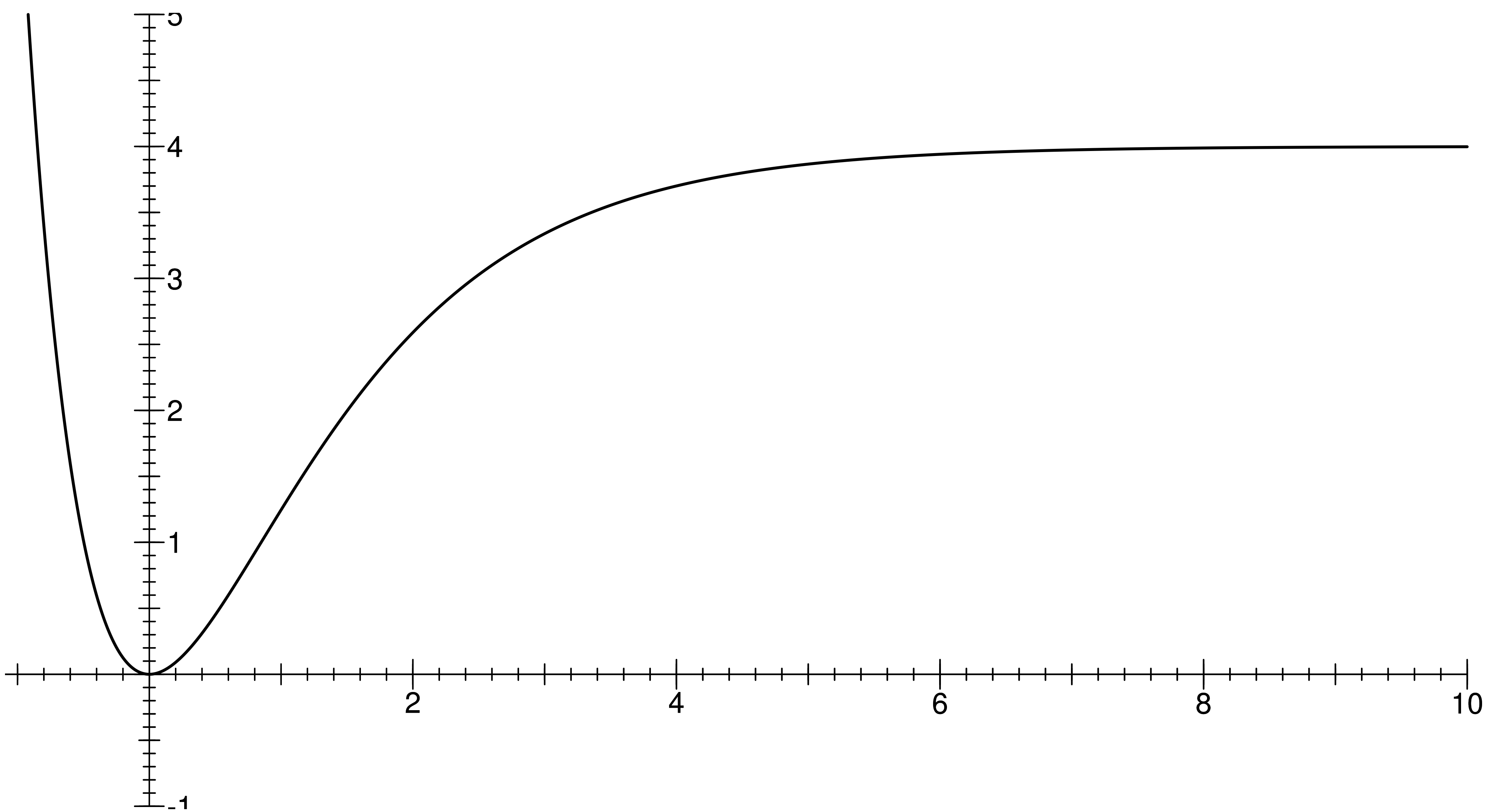
LEGENDRE TRANSFORM

IN PARTICULAR, WHEN $f(X) = \frac{1}{2g^2}X^2$

THE POTENTIAL IS $(1+Y)^{-2}\tilde{f}(Y) = \frac{g^2}{2}\left(1 - e^{-\sqrt{2/3}\phi}\right)^2$

THE "STAROBINSKY" POTENTIAL (VERTICAL AXIS SCALE MULTIPLIED BY $8/g^2$)



HIGHER ORDER CORRECTIONS: WHICH SCALE?

$$R + \frac{1}{2g^2}R^2 \to Rf(R/g^2),\ f(x) = 1 + \frac{1}{2}x + O(1)x^4 + \ldots$$

WHEN CURVATURE IS $O(g^2)$ ALL TERMS ARE EQUAL

IS IT POSSIBLE TO GET ANOTHER FACTOR $O(g^2)$

IN FRONT OF THE HIGHER CURVATURE CORRECTIONS?

WHAT ABOUT CHAOTIC INFLATION?

T.B.C.........

SUPERSYMMETRIZATION OF f(R) GRAVITY

- GRAVITON (OFF SHELL) DEGREES OF FREEDOM: 10-4=6
- GRAVITINO DEGREES OF FREEDOM 16-4=12
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GAUGE INVARIANCE $B_{\mu\nu} \rightarrow B_{\mu\nu} + \partial_{[\mu}\xi_{\nu]},\ A_\mu \rightarrow A_\mu + \partial_\mu \xi$

OLD MINIMAL AND NEW MINMAL DIFFER BY NON PROPAGATING DEGREES OF FREEDOM IN STANDARD “EINSTEIN” SUPERGRAVITY; WHEN HIGHER CURVATURE TERMS ARE INTRODUCED THEY AUXILIARY FIELDS PROPAGATE AND THE TWO FORMALISMS ARE NO LONGER EQUIVALENT

CONSIDER FIRST THE SUPERSYMMETRIZATION OF THE ACTION

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ANALYSIS IN THE NEW MINIMAL FORMALISM: 1988, CECOTTI, FERRARA, M.P. AND SABHARWAL

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IN OLD-MINIMAL, THE BOSONIC PART OF THE ACTION IS

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ONE SCALAR

GRAVITON PLUS ONE SCALAR

THE OLD MINIMAL SUPERSYMMETRIZATION OF ACTIONS WITH HIGHER POWERS OF THE SCALAR CURVATURE CONTAINS FOUR SCALARS. IN THE SIMPLEST REALIZATIONS OF INFLATIONARY POTENTIALS THESE SCALARS MAY BECOME UNSTABLE DURING SLOW ROLL.

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THE SUPERMULTIPLET CONTAINING THE DEGREES OF FREEDOM RELEVANT TO A NEW MINIMAL SUPERSYMMETRIZATION OF ACTIONS WITH HIGHER POWERS OF THE SCALAR CURVATURE CAN BE WRITTEN AT THE FULL NON-LINEAR LEVEL USING SUPECONFORMAL CALCULUS

CONFORMAL CALCULUS: (ADD DILATON DOF AND WEYL INVARIANCE TO REMOVE IT)

$$g_{\mu\nu} \to \hat{g}_{\mu\nu} \equiv \phi^2 g_{\mu\nu} \ s.t. \ g_{\mu\nu} \to \Omega^2 g_{\mu\nu}, \ \phi \to \Omega^{-1}\phi$$

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SUPERCONFORMAL CALCULUS: (ADD DILATON CHIRAL MULTIPLET AND SUPER-WEYL INVARIANCE TO REMOVE IT)

THE BOSONIC PART OF SUPER-WEYL CONTAINS SCALE PLUS CHIRAL TRANSFORMATION: SUPER-WEYL MULTIPLETS ARE CLASSIFIED BY CHARGE AND SCALING DIMENSION

THE NEW MINIMAL EINSTEIN ACTION DEPENDS ON A CHIRAL COMPENSATOR WITH (SCALING DIMENSION,CHIRAL WEIGHT)=(1,1) AND A LINEAR MULTIPLET WITH WEIGHTS (2,0)

$$\mathcal{L}_E = [LV_R]_D, \qquad V_R = \log(L/S\bar{S})$$

$\theta^2\bar{\theta}^2$ TERM

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$$D^2 L = \bar{D}^2 L = 0 \to L = ... + \bar{\theta}\sigma^\mu\theta A_\mu + .., \ \partial_\mu A^\mu = 0$$

LINEAR MULTIPLET

THE ACTION IS INDEPENDENT OF THE CHIRAL COMPENSATOR BECAUSE IT CAN BE SCALED TO A CONSTANT WITH A GAUGE TRANSFORMATION PARAMETRIZED BY A CHIRAL SUPERFIELD

$$S \to S' = e^{\Omega} S,\ S' = 1, \qquad V_R \to V_R + \Omega + \bar{\Omega}$$

THE EINSTEIN TERM IS INVARIANT BECAUSE

$$[L(\Omega + \bar{\Omega})]_D = 0$$

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HIGHER ORDER TERMS ARE WRITTEN IN TERMS OF THE GAUGE-INVARIANT FIELD STRENGTH

$$W_\alpha(V_R) = \bar{D}^2 D_\alpha V_R = \theta_\alpha R + ...$$

THE NEW MINIMAL $R + \alpha R^2$ ACTION

$$\mathcal{L} = [LV_R]_D + \frac{1}{2g^2}[W_\alpha^2(V_R)]_F + c.c.$$

θ^2 TERM

THE ACTION IS DUAL TO A STANDARD SUPERGRAVITY ACTION DESCRIBING GRAVITON+GRAVITINO PLUS A MASSIVE VECTOR MULTIPLET [1,(2)1/2, 0] (CECOTTI, FERRARA, M.P., SABHARWAL, 1988; RIOTTO, KEHAGIAS, 2013)

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TRICK: INTRODUCE AN UNCONSTRAINED REAL MULTIPLET AS LAGRANGE MULTIPLIER: R

$$\mathcal{L} = -[S\bar{S}e^{U}U]_D + [R(S\bar{S}e^{U} - L)]_D + \frac{1}{2g^2}[W_\alpha^2(U)]_F + c.c.$$

ACTION DOES NOT DEPEND ON S BECAUSE OF GAUGE INVARIANCE

$$S \to Se^{Y}, \qquad U \to U - Y - \bar{Y}, \qquad R \to R - Y - \bar{Y}$$

$$\mathcal{L} = -[S\bar{S}e^U U]_D + [R(S\bar{S}e^U - L)]_D + \frac{1}{2g^2}[W_\alpha^2(U)]_F + c.c.$$

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SOLVE E.O.M. OF LINEAR MULTIPLET L TO GET

$$R = T + \bar{T}$$

REDEFINE $\quad S \to Se^{-T}$

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ACTION DESCRIBES A MASSIVE VECTOR MULTIPLET

$$\mathcal{L} = -[S\bar{S}(U - T - \bar{T})e^{(U-T-\bar{T})}]_D + \frac{1}{2g^2}[W^2(U)]_F + c.c.$$

THIS IS A PARTICULAR CASE OF THE GENERAL N=1 ACTION WHERE THE U(1) GAUGED BY THE VECTOR FIELD IS IN THE BROKEN PHASE

$$U e^{U} \rightarrow e^{(2/3) J(U - T - \bar{T})}, \qquad J(C) = \frac{3}{2}(C - \log C)$$

STUCKELBERG FIELD

KAEHLER POTENTIAL

$$T \rightarrow T + \Omega, \qquad U \rightarrow U + \Omega + \bar{\Omega}$$

THE BOSONIC ACTION CAN BE COMPUTED USING THE GENERAL FORMULAS OF N=1 SUPERGRAVITY

$$\mathcal{L} = \frac{1}{2}R - \frac{1}{2}J''(C)\partial_\mu C\partial^\mu C - \frac{1}{4g^2}F_{\mu\nu}(B)F^{\mu\nu}(B) - \frac{1}{2}J''(C)B_\mu B^\mu - \frac{g^2}{2}J'^2(C)$$

DEGREES OF FREEDOM: ONE SCALAR AND ONE MASSIVE VECTOR

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DEGREES OF FREEDOM: ONE SCALAR AND ONE MASSIVE VECTOR

FOR THE KAEHLER FUNCTION $\quad J(C) = \frac{3}{2}(C - \log C)$

REDEFINE $\quad C = \exp(\sqrt{2/3}\phi)$

THE POTENTIAL IS $\quad V = \frac{9}{8}g^2(1 - e^{-\sqrt{2/3}\phi})^2$

SCALE-INVARIANT SUPERGRAVITY

NO EINSTEIN TERM

$$\mathcal{L} = [B(S\bar{S}e^U - L)]_D + \frac{1}{2g^2}[W_\alpha^2(U)]_F + c.c.$$

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L E.O.M. GIVE STANDARD SUPERGRAVITY WITH A FLAT DIRECTION IN THE POTENTIAL

$$B = T + \bar{T}$$

$$\mathcal{L} = [S\bar{S}(T + \bar{T})e^U]_D + \frac{1}{2g^2}[W^2(U)]_F + c.c.$$

HIGHER CURVATURE CORRECTIONS

WE WANT TO FIND THE SUPERSYMMETRIC COMPLETION OF R^n TERMS

CHIRAL PROJECTOR

$$(w, w-2) \xrightarrow{\Sigma} (w+1, w+1)$$

$$\mathcal{L} = [LV_R]_D + \frac{1}{2g^2}[W^2]_F + \sum_{klp} a_{klp} \left[\frac{W^2 \bar{W}^2}{L^2} \left(\bar{\Sigma} \frac{W^2}{L^2} \right)^k \left(\Sigma \frac{\bar{W}^2}{L^2} \right)^l \left(\frac{D^\alpha W_\alpha}{L} \right)^p \right]_D$$

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SUPERSYMMETRY FORBIDS R^3

THE BOSONIC ACTION CONTAINS THE TERMS

$$\mathcal{L} = \frac{1}{2}R + \frac{1}{18g^2}R^2 + \sum_{klp} a_{klp} R^{4+p+2k+2l}$$

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BUT ALSO THE TERMS

$$\sum_{klp} a_{klp}(F^{+2} - D^2)^{1+k}(F^{-2} - D^2)^{1+l} C^{2+2k+2l}(DC)^p$$

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(ANTI) SELF-DUAL FIELD STRENGHT

AUXILIARY FIELD

DANGEROUS CORRECTIONS:

$$a_{klp} \sim g^{-(6+4k+4l+2p)}$$

BECAUSE THE HIGHER-ORDER TERMS BECOME O(1) AT THE INFLATION SCALE

$$R \sim g^2$$

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BECAUSE THE HIGHER-ORDER TERMS BECOME O(1) AT THE INFLATION SCALE

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BUT BEHAVIOR IS TOO SINGULAR IN THE "UNHIGGSED" LIMIT $g \to 0$

NORMALIZE VECTOR FIELD $B_\mu \to g B_\mu$

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REGULARITY OF BORN-INFELD TERMS

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E.G. DURING SLOW ROLL THE FIRST CORRECTION (R^4)
IS AT MOST

$$g^{-4}R^4 \sim R^2 \ll \frac{1}{18g^2}R^2, \qquad g \sim 10^{-4} - 10^{-5}$$

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- WE HAVE HERE A NEW SETTING FOR FINDING SUCH A POTENTIAL

$$J = C^2/2, \qquad V = \frac{g^2}{2}C^2$$

RATHER GENERAL COUPLING TO MATTER

$$\begin{aligned}\mathcal{L} &= -[S\bar{S}e^{U}(U+\Phi(U,Z,\bar{Z}))]_D + [R(S\bar{S}e^{U}-L)]_D \\ &\quad + \frac{1}{2g^2}[W_\alpha^2(U)]_F + [S^3W(Z)]_F + c.c.\end{aligned}$$

GAUGE INVARIANT UNDER

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SOLVE L E.O.M. GET STANDARD SUGRA LAGRANGIAN WITH (BROKEN) GAUGED R-SYMMETRY

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COMPOSITE MULTIPLET V_R GAUGES THE R-SYMMETRY

SOLVE L E.O.M. GET STANDARD SUGRA
LAGRANGIAN WITH (BROKEN) GAUGED R-SYMMETRY

CFR. LUST-KOUNNAS-TOUMBAS arXiv: 1409.7076
FERRARA-PORRATI arXiv: 1506.01566

SCALAR POTENTIAL

A LOT OF CANCELATIONS LEAD TO

$$V = W_I \Phi^{I\bar{J}} \bar{W}_{\bar{J}} + \frac{g^2}{2} D^2$$

$$D = -6e^{-\sqrt{2/3}\phi} + 6 + \text{terms quadratic in matter fields } z$$

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SO POTENTIAL REDUCES TO PURE STAROBINSKY AT STATIONARY POINT FOR MATTER FIELDS WHEN

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hep-ph/9606342

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PREVIOUS USE OF D TERMS FOR INFLATION:
BINETRUY-DVALI-KALLOSH-VAN PROEYEN
hep-ph/9606342 hep-th/0402046

CONCLUSIONS

- INFLATIONARY f(R) SCENARIOS CAN BE EMBEDDED IN SUPERGRAVITY
- THE NEW MINIMAL FORMALISM IS PARTICULARLY SUITED TO STUDY f(R) THEORIES BECAUSE IT ADDS ONE SINGLE SCALAR TO THE GRAVITATIONAL SUPERMULTIPLET, WHICH IS UNEQUIVOCALLY IDENTIFIED WITH THE INFLATON
- POTENTIALLY DANGEROUS HIGHER-CURVATURE CORRECTIONS ARE FORBIDDEN BY A DECOUPLING ARGUMENT
- THE D-TERM POTENTIAL CAN BE EMBEDDED INTO A POTENTIAL CONTAINING D AND F TERMS

- LAST BUT NOT LEAST: THE LAGRANGIAN DUAL TO NEW-MINIMAL HIGH CURVATURE POTENTIALS GIVES THE SIMPLEST AND MOST NATURAL REALIZATION IN SUPERGRAVITY OF QUADRATIC-POTENTIAL CHAOTIC INFLATION

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- WORK DESCRIBED DONE IN COLLABORATION WITH S. FERRARA, A. LINDE, R. KALLOSH, A. KEHAGIAS AND A. SAGNOTTI