Magnetically-Induced Holographic Composite Inflation

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Bibliography

Collaboration with
Amjad Ashoorioon, Moslem Ahmadvand

- **Confronting the Magnetically-Induced Holographic Composite Inflation with Observation**
  arXiv:20103.08362

Motivation (1/2)

- One of the well-motivated scenarios which may describe the inflation physics is strongly coupled gauge theories in which the inflaton field emerges as a bound state breaking a chiral symmetry at some energy scale.
  [Evans:2010, Channuie:2011]
- In fact, in this effective theory above this scale, there is no such a bound state and instabilities of the inflaton mass, due to radiative corrections, can be circumvented.
  [Kachru:2003, McAllister:2005, Chen:2008]

Motivation (2/2)

- In this talk, we investigate a strongly coupled gauge theory for inflation introduced in which chiral symmetry breaking occurs due to a background magnetic field.
  [Evans:2010]
- In such theories we cannot use conventional perturbative methods.
- One of the approaches through which many features of strongly coupled systems can be studied is AdS/CFT correspondence.
  [Maldacena:1997, Gubser:1998, Witten:1998]
- Employing this tool, the model is constructed from a D3/D7 brane system in the AdS/QCD framework.
  [Karch:2002, Erlich:2005]

Holographic setup (1/4)

	t	x_1	x_2	x_3	x_4	x_5	x_6	x_7	L	ω
D3	×	×	×	×						
D7	×	×	×	×	×	×	×	×		

$$ds^2 = g_{\mathrm{UV}}^{-1}\left[\frac{r^2}{R^2}\left(g_{tt}dt^2 + g_{ij}dx^i dx^j\right) + \frac{R^2}{r^2}\left(d\rho^2 + \rho^2 d\Omega_3^2 + dL^2 + d\omega^2\right)\right], \tag{1}$$

- where g_{UV} is the asymptotic value of the gauge coupling,
- $r^2 = \rho^2 + L^2$ is the radial coordinate corresponding to the energy scale of the gauge theory,
- $\omega = 0$ where ω is the other coordinate perpendicular to the D7 brane
- $R = (4\pi g_{\mathrm{UV}}^2 N_c \alpha'^2)^{1/4}$ is the AdS length scale,
- $\alpha' \sim l_s^2$ is the string tension, l_s is the string length,
- $g_{tt} = -1$, $g_{ij} = a(t)^2\delta_{ij}$ and $a(t)$ is the scale factor.

Holographic setup (2/4)

The condensation which breaks the chiral symmetry of the theory is entered by studying the embedding function, $L(\rho, t)$.

- According to the Dirac-Born-Infeld (DBI) action of the D7-brane, the action for $L(\rho, t)$ is

$$S_{\mathrm{DBI}} = -T_7 R^4 \int d^4x d\rho \frac{e^{\phi}\ a(t)^3 \rho^3}{\rho^2 + L^2} \sqrt{-\dot{L}^2 + (\rho^2 + L^2)^2 (1 + L'^2)}, \tag{2}$$

  where $T_7 = \frac{1}{2(2\pi)^5 g_{\mathrm{UV}}^2 \alpha'^4}$ and $L' \equiv \partial_\rho L$, and $\dot{L} \equiv \partial_t L$.

- Running of the gauge coupling can be parameterized as

$$e^{\phi} = g_{\mathrm{UV}}^2 \beta(r) = g_{\mathrm{YM}}^2(r). \tag{3}$$

  The $\beta(r)$ function is related to the background magnetic field, B,

$$\beta = \sqrt{1 + \frac{B^2}{(\rho^2 + L^2)^2}}, \tag{4}$$

  [Filev:2007, Jensen:2010, Evans:2010]

Holographic setup (3/4)

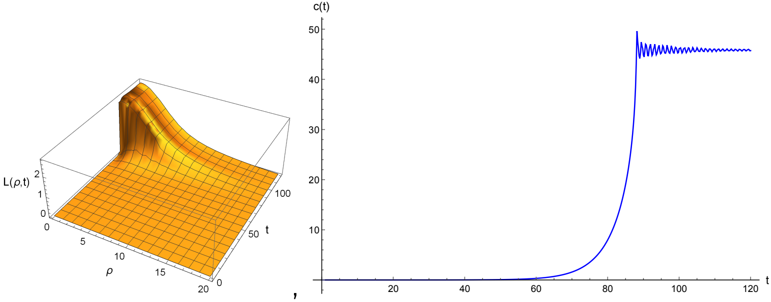


Figure: Using the iterative approach and solving equation of motion, the embedding function $L(\rho, t)$ is found.

UV asymptotic embedding solution is corresponded to [Babington:2003]

$$L(\rho, t) = m + \frac{c(t)}{\rho^2} \tag{5}$$

where m is proportional to the quark-like mass, $m_q = m/(2\pi\alpha')$, and $c(t)$ is associated to the condensate $\langle \bar{q}q \rangle(t) = c(t)/(2\pi\alpha')^3$ [Erdmenger:2007].

Holographic setup (4/4)

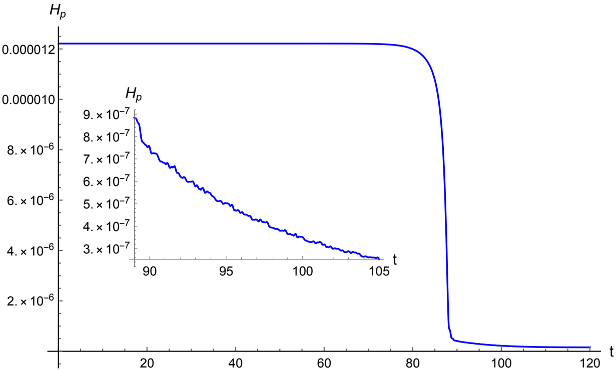


Figure: The Hubble parameter is displayed for $N_c = 10^7$, $\lambda = g_{\mathrm{UV}}^2 N_c = 1.4 \times 10^6$ and $n_p = 8 \times 10^5$. As expected, the Hubble parameter has a decreasing oscillatory behavior at late times, after inflation ends.

Slow-roll inflation

- The first slow-roll parameter, quantifying whether inflation takes place at a given time is written as

$$\epsilon \equiv -\frac{\dot{H}}{H^2}\,. \tag{6}$$

- To maintain inflation for sufficient amount of time, the second condition, which should be less than one during this period, is given by

$$\eta \equiv \epsilon - \frac{\dot{\epsilon}}{2\epsilon H} = \epsilon - \frac{\dot{\epsilon}}{2n_p\epsilon H_p}\,. \tag{7}$$

- The amount of inflation can be quantified in terms of the number of e-folds as

$$N_e \equiv \int_{t_{\rm CMB}}^{t_{\rm end}} dt\ H = \int_{t_{\rm CMB}}^{t_{\rm end}} dt\ n_p H_p\,. \tag{8}$$

Observable Parameters(1/2)

- The dimensionless power spectrum of scalar fluctuations is defined as

$$\Delta_s^2 \equiv \frac{1}{8\pi^2}\frac{H_p^2}{\epsilon}\,. \tag{9}$$

- The deviation of scalar power spectrum from scale-invariance can be parameterized in terms of scalar spectral index, which is defined in terms of slow-roll parameters as

$$n_s = 1 + 2\eta - 4\epsilon\,. \tag{10}$$

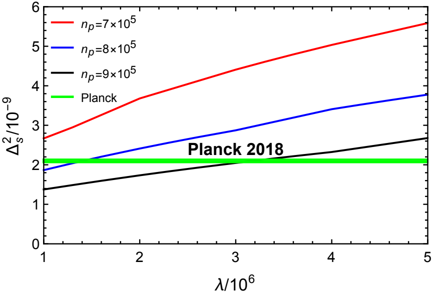
- Another important parameter is the tensor-to-scalar ratio, which is indeed a measure of magnitude of the tensor power spectrum, $r \equiv \Delta_t^2/\Delta_s^2$. We can obtain this ratio at $t_{\rm CMB}$ from the first slow-roll parameter

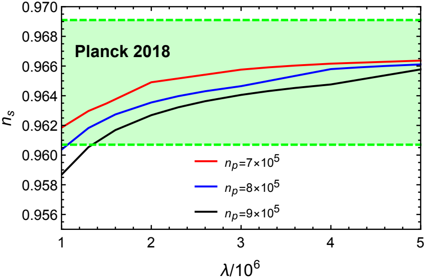
$$r \simeq 16\epsilon\,. \tag{11}$$

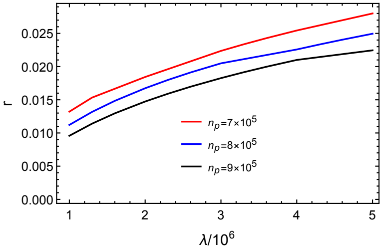
  The current upper limit on r is $r < 0.056$. [Akrami:2018, Aghanim:2018]

Observable Parameters(2/2)

For three different values of n_p, $N_c = 10^7$ and $N_e = 60$.







The Lyth bound

For the obtained $r \gtrsim 0.01$ of the model, one would expect a large field model of inflation. We now try to verify whether this bound is satisfied in our model. One should note that the condensate is a mass dimension cubed composite scalar field,

$$\langle \bar{q} q \rangle = R^3 c / (2\pi\alpha')^3 \,, \tag{12}$$

and in order to transform it to a canonically normalized mass dimension one scalar field, it should be divided by a mass dimension squared parameter,

$$\Delta\phi \sim \frac{R^3 \Delta c}{(2\pi\alpha')^3 \Lambda^2} \,, \tag{13}$$

where Λ is the cut-off of the theory. On the other hand, the UV cutoff of the theory should be greater than the symmetry breaking scale $\Lambda > R\, c^{1/3}/(2\pi\alpha')$, In Planck units where $R = n_p$ and hence $l_s \sim 10^4$, $\Delta\phi \lesssim 10^{-3}$. Therefore, despite predicting $r \gtrsim 0.01$, the excursions of the canonical field remains below M_p.

Conclusion (1/2)

We showed that the magnetically induced symmetry breaking case, can also cause a long enough inflationary period, which incidentally produces signatures compatible with the latest Planck results.

- We consistently solved for the four-dimensional spacetime and found the embedding function of the D7 brane, through an iterative method. This allowed us to see both the inflationary epoch and ensuing reheating phase in which the condensate oscillating phase, in a unified picture.
- We found sets of parameters for the microscopical parameters of model that the observables, including the amplitude of density perturbation, the scalar spectral index and the tensor-to-scalar ratio are all in agreement with Planck bounds [Akrami:2018].
- Although the model produces a large amount of tensor-to-scalar ratio, in violation of the Lyth bound [Lyth:1996], the canonical mass dimension one scalar field displacement remains below the Planck mass.

Conclusion (2/2)

It will be interesting to study the model further, particularly in connection to the mechanism for reheating after inflation.

THE END