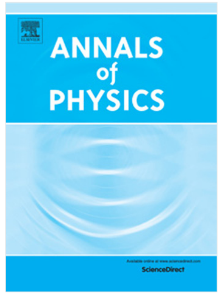
Accepted Manuscript



On the stability of cubic galileon accretion

Santiago Esteban Perez Bergliaffa, Rodrigo Maier

PII: S0003-4916(17)30180-X
DOI: http://dx.doi.org/10.1016/j.aop.2017.06.014
Reference: YAPHY 67421

To appear in: *Annals of Physics*

Received date : 9 March 2017
Accepted date : 21 June 2017

On the Stability of Cubic Galileon Accretion

Santiago Esteban Perez Bergliaffa and Rodrigo Maier*
Departamento de Física Teórica, Instituto de Física, Universidade do Estado do Rio de Janeiro, Rua São Francisco Xavier 524, Maracanã, Rio de Janeiro, Brasil.

(Dated: June 20, 2017)

We examine the linear stability of the nongravitating steady-state galileon accretion for the case of a Schwarzshild black hole. Considering the galileon action up to the cubic term in a static and spherically symmetric background we obtain the general solution for the equation of motion which is divided in two branches. By perturbing this solution we define an effective metric which determines the propagation of fluctuations. In this general picture we establish the position of the sonic horizon together with the matching condition of the two branches on it. Restricting to the case of a Schwarzshild background, we show, via the analysis of the energy of the perturbations and its time derivative, that the accreting field is linearly stable.

PACS numbers: 04.50.Kd, 04.40.Nr, 11.10.-z

I. INTRODUCTION

The description of the late-time accelerated expansion of the universe has motivated the study of many theories of modified gravity in the infrared limit (see [1] for a review). An example of such theories which displays interesting properties is the so-called galileon model [2] (see [3] for a covariant generalization), which owes its name to an internal symmetry in which the gradient of the scalar field is shifted by a constant [1]. Such a symmetry constrains the Lagrangian of the theory to only five terms in 4 spacetime dimensions [2]. The galileon model is the most general scalar-tensor theory with equations of motion that contain no more than two derivatives (hence avoiding the Ostrogradski instability [5]). Other important features [2] are (i) that it allows for the implementation of the Vainshtein mechanism [6, 7], and (ii) the non-quadratic kinetic coupling leads to the propagation of perturbations in an effective metric, as we shall see below [8].

The particular model that keeps only the first three terms of the Lagrangian of the galileon model, namely the cubic galileon, has been applied to the description of several phenomena, such as compact objects [9] and black holes in a cosmological setting [10]. The model was shown to describe dark energy with well-behaved perturbations in [4], and its predictions at the level of the Solar system were presented in [11]. Limits on the coupling constants of this model coming from terrestrial experiments have been obtained in [12], and from cosmological observations in [13]. The model has also been used to study the large-scale stucture problem [14] and tested with the Coma Cluster [15]. As with every new theory, it is important to continue the examination of the consequences of the cubic galileon, in particular by checking the existence and stability of relevant solutions [2] , and the interaction of the fields of the theory with given environments. This latter task that was initiated in [16], where the steady-state and spherically symmetric accretion of a galileon field onto a Schwarzchild black hole in the test fluid approximation was analyzed (both for the cubic galileon, and for the combination of the second and fourth terms of the galileon model). Specifically, the conditions for the existence of the critical flow were established, as well as the dependence of the position of the sonic horizon with the parameters of the theory. Here we shall tackle the problem of linear stability accretion of a test cubic galileon analyzed in [16], using a method developed by Moncrief [17]. Such a method is based on the evaluation of the sign of the time derivative of the energy of the perturbations in a given volume [3]. A negative sign together with the positivity of the energy of the perturbations implies linear stability. By use of Moncrief's method, we shall show that the abovementioned system is linearly stable.

II. PRELIMINARY SETTING

Let us consider a test galileon field ϕ whose action reads

$$S_\phi = \int \sqrt{-g}\left[\frac{1}{2}\nabla_\mu\phi\nabla^\mu\phi + \beta(\nabla_\mu\phi\nabla^\mu\phi)\Box\phi\right]d^4x, \tag{1}$$

* rodrigo.maier@uerj.br

[1] This model belongs to the class of theories with kinetic gravity braiding introduced in [4].
[2] Strong-gravity solutions (such as black holes and neutron stars) of Horndeski theory were studied in [10] .
[3] For other applications of this method see [18] and references therein.