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Written assessment of the doctoral dissertation of Michele Grasso

Dear Members of the Scientific Council,

I would like to present my assessment of the doctoral dissertation titled «Bigonlight: A new package for computing optical observables in numerical relativity» which has been submitted by PhD Candidate Michele Grasso.

General relativity is a geometric description of gravity where a free particle will travel on a trajectory called a geodesic which generalises the concept of linear motion to non-flat geometries. This is in particular true for photons that carry the information we receive in our telescopes: on their way through the Universe, their paths get influenced by the presence of spacetime curvature. A well-known consequence is the phenomenon of gravitational lensing. In the limit where this effect is small in the sense that there is still a smooth map between the patch of spacetime we observe and the image we take with our telescopes (weak-lensing regime), a thorough theoretical framework exists to describe this effect. This framework establishes the exact connection between an infinitesimal change in observed angular position and the corresponding spatial separation of the light paths at the source. By reciprocity (exchanging the role of source and observer) it also allows to relate an infinitesimal angle at the source to a separation at the observer. With these basic ingredients one can compute optical observables like magnification, shear (distortion of images) and luminosity distance. The proper motion of the source and observer additionally give rise to changes in the observed photon frequency (redshift) as well as to special-relativistic aberration at the observer.

What this thesis sets out to do is to generalise this existing framework in order to include additional observables. For instance, one can ask how an infinitesimal spatial displacement of the observer is related to an infinitesimal change of observed angular position of a fixed source – this gives rise to the concept of parallax. One can also consider the time evolution of observed angular position and redshift along the path of the observer, i.e. so-called drift effects. In order to incorporate all these possible observables into a unified framework, the concept of bilocal geodesic operators (BGOs) is introduced. Following closely the approach that was already developed for weak lensing, the equations for the BGOs are worked out first in theory in Chapter 3, after some preliminaries were set out in Chapters 1 and 2. The

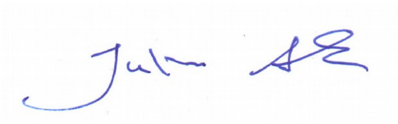
Candidate then presents a numerical tool that seeks to solve these equations for a given spacetime geometry. The latter may be specified either as a mathematical solution or in form of a numerical solution, e.g. from a computer simulation (numerical relativity).

The Candidate goes on to present two scientific publications, Chapters 4 and 5, in which the numerical tool (a Mathematica package called BiGONLight) is applied to some test cases and partially validated, observing mostly a very high numerical precision. Due to the high degree of symmetry present in most of the settings the conclusions, summarised again in Chapter 6, may be a bit preliminary, and it will be interesting to see this framework applied to real-world situations. However, the framework is conceptually very powerful and has the potential to make significant contributions to the advancement of the field in the future. Indeed, as the Candidate notes, the measurement of drift effects may be technically feasible in the near future, opening up a new window into the dynamics of our Universe.

With this work the Candidate demonstrates that he has a good grasp of the concepts of general relativity and that he masters the mathematical language to formulate problems and describe their solutions in a rigorous way. Moreover, the central scientific problem is tackled with an innovative methodology that easily incorporates proven results but also makes new ones readily accessible. On the numerical side the Candidate is able to employ the high-level symbolic programming framework of Mathematica. The Candidate is co-author of three peer-reviewed articles that are closely related to this dissertation – two of which feature as Chapters 4 and 5, respectively. Apart from some minor oversights the manuscript overall is scientifically sound and of appropriate length and detail.

Therefore, I conclude that the presented dissertation meets the formal requirements for a Ph.D. thesis and recommend admission of the Candidate to the subsequent stages of the procedure, including the public defense.

Sincerely,



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