高階無窮薄氣體盤自重力計算

The Astrophysical Journal Supplement Series

Vol. 242/ issue 2/page 1-17

2019/05/31

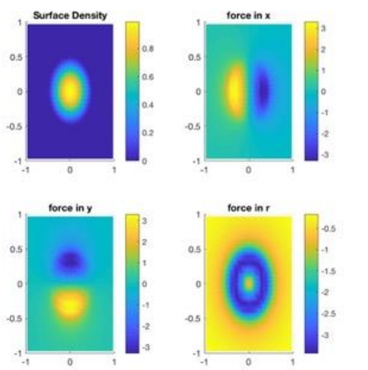
嚴健彰副教授／理工學院數學系

Self-gravitational Force Calculation of High-order Accuracy for Infinitesimally Thin Gaseous Disks

七夕情人節仰望天際可窺見牛郎星與織女星，連接兩端的銀河正是我們所處的銀河系，銀河的中心有一個無窮薄的氣體盤．現今望遠鏡的技術與日俱增，使科學家對銀河中心的結構與形成愈發好奇．在星體的重力與氣體盤的自重力的作用下，探究觀測結果的物理機制，需藉由理論與數值模擬來驗證是研究星系動態演化可行的方法． 模擬需包含流體與自重力計算，而自重力的計算所需時間隨者網格是以平方增加，一個模擬需要 1 天的時間，增加一倍格點時就需 4 天，進一步針對一個星系做模擬研究，需要模擬十幾次以上才能找到合適相對應於觀測的結果，故尋找快速且精準度高的方法是我們的目標．在 2014 年由嚴健彰，譚遠培，葉懷哲與張康，透過解析方式計算奇異核積分，並藉由快速傅立葉轉換的幫助，發展出一個二階準確度與快速的計算．其所提方法已用於中央研究院天文所發展的大火程序中．進一步應用此方法所獲得的研究成果，主要有林蓮宣博士，其博士論文應用於星系 NGC 6782, NGC 1097, NGC 1300 研究等等．因原方法其計算對於更高階精準度時，會增加計算時間，2016 年吳蕊竹同學和我，應用樣條函數為基底函數展開一般函數的表達式，在不增加計算量的情況下，依然達到比二階更高的準確度，天下沒有白吃的午餐，我們必須在計算前用解析的方式計算所需的公式先算出，其計算又經過香港中文大物理系王祥旭教授的簡化與交大應數系薛名成教授理論分析，最後於 2019 發表在天文期刊上．

（a） Milky Way

(b) NGC 4314



(c) 模擬表密度為圓盤的力

相關連結 https://iopscience.iop.org/article/10.3847/1538-4365/ab1a33

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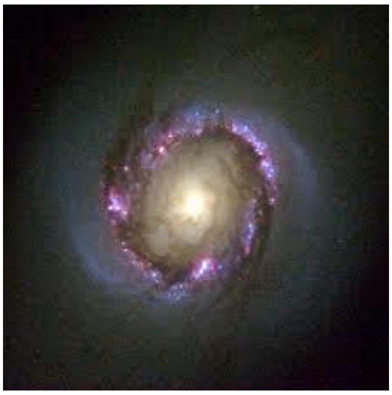
Chien-Chang Yen, Ph.D., Associate Professor

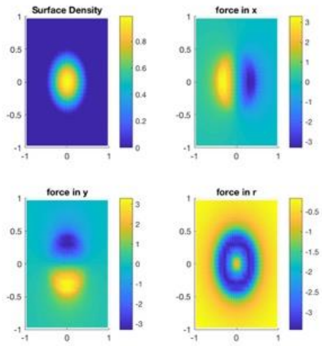
Mathematics Department

College of Science and Engineering/Fu Jen Catholic University

Self-gravitational Force Calculation of High-order Accuracy for Infinitesimally Thin Gaseous Disks without Artificial Boundary Conditions

On Valentine, you can see the Altair in Aquila and the Vega in Lyra in the sky. The Milky way where we live connects these two galaxies. There is an infinitesimal thin gaseous disk in the center of the Milky Way. Nowadays, the high resolution of telescopes makes scientists be more curious on the structure and activities of the galactic center region. It is needed to be verified by theory and numerical simulations for observations of the physical mechanism under the influence of the gravity of stars and the self-gravity of the gaseous disk. Numerical simulations are significant to study the dynamic evolution of galaxies. However, the simulation requires to include both fluid and self-gravitational forces calculations. The time complexity of a direct numerical approach is growth in quadratic. For instance, if a simulation requires 1 days, then it takes 4 days for double grid zones. Furthermore, a simulation study of a galaxy, it is often necessary to simulate more than ten simulations to find an accepted result compared with the observations. Our goal is to find a fast and highly accurate method. In 2014, Chien-Chang Yen, Ronald E. Taam, Ken Huai-Che Yeh, Kang C. Jea develop a method involving a calculation of the singular kernel integrals in analytic, and with the help of fast Fourier transform (FFT), the proposed method is of second-order accuracy and nearly linear complexity. The proposed method is used in the Antares codes developed by the Institute of Astronomy and Astrophysics, Academia Sinica. The research results obtained by applying this method mainly include Dr. Lien-Hsuan Lin and her doctoral dissertation on the galaxies NGC 6782, NGC 1097, NGC 1300, etc. For higher order accuracy more than second order, the time complexity will increase exponentially. In 2016, Miss Rui-Zhu Wu and I used the spline functions as the basis functions on an expansion of surface density. We achieve higher accuracy than the second order remaining the same time complexity. On the other hand, there is no free lunch. We must calculate the required formulas in analytic before numerical simulations. The calculation has been simplified by Professor Hsiang-Hsu Wang in the Department of Physics of the Chinese University of Hong Kong. The theoretical analysis is done by Professor Ming-Cheng Shiue from the Department of Applied Mathematics, National Chiao Tung University. This research has been published in the astronomical journal in 2019 May.





（a） Milky Way (b) NGC 4314 (c) Simulation of surface density and forces

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