Spectral methods for computing self-gravity: strengths and limitations

Steven Rendon Restrepo

March 2024

Although not always the dominant force throughout all spatial regions and evolutionary stages of Protoplanetary discs (PPDs), the disk gravity on itself, known as self-gravity (SG), is nonetheless ubiquitous. This interaction becomes particularly significant in the early ages of discs (class 0/I disks) or in the outskirts of class II discs, where the gravitational instability may operate [**1**]. In a wider context SG is expected to be key in all planet formation scenarios for explaining the formation of objects bound by gravity, such as the scenario of vortices [**2,3**]. Recent theoretical and numerical studies have even demonstrated that SG combined with non-ideal MHD effects is key for explaining the generation of magnetic fields, an effect known as gravitoturbulent dynamo [**4,5**].

The numerical assessment of SG involves either computing the integral defining the gravitational potential or solving Poisson's equation. Various methods are employed for this purpose, including direct sum, multigrid, tree-based, and notably spectral methods [**6**]. Spectral methods are particularly valued for their computational efficiency, as they demonstrate scalability as $N \log(N)$ (for a 2D problem).

In this talk, I propose to provide an overview of spectral methods used in the computation of SG in both global 2D simulations and 3D shearing boxes. I will focus on discussing the advantages associated to these methods, while also addressing the constraints that can sometimes restrict their applicability to certain astrophysics scenarios.

1 Bibliography

[**1**] Kratter, K. & Lodato, G. 2016, ARAA, 54, 271.
[**2**] Rendon Restrepo, S. & Barge, P. 2023, A&A, 675, A96.
[**3**] Rendon Restrepo, S. & Gressel, O. 2023, poster PF-07-003, PPVII [**4**] Riols, A. & Latter, H. 2018, MNRAS, 474, 2212.
[**5**] Riols, A. & Latter, H. 2019, MNRAS, 482, 3989.
[**6**] Moon, S., Kim, W.-T., & Ostriker, E. C. 2019, ApJ, 241, 24.