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A systematic development of Jeans' criterion with rotation for gravitational instabilities.

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Summary: An inviscid fluid model of a self-gravitating infinite expanse of a uniformly rotating adiabatic gas cloud consisting of the continuity, Euler's, and Poisson's equations for that situation is considered. There exists a static homogeneous density solution to this model relating that equilibrium density to the uniform rotation. A systematic linear stability analysis of this exact solution then yields a gravitational instability criterion equivalent to that developed by Sir James Jeans in the absence of rotation instead of the slightly more complicated stability behavior deduced by Subrahmanyan Chandrasekhar for this model with rotation, both of which suffered from the same deficiency in that neither of them actually examined whether their perturbation analysis was of an exact solution. For the former case, it was not and, for the latter, the equilibrium density and uniform rotation were erroneously assumed to be independent instead of related to each other. Then this gravitational instability criterion is employed in the form of Jeans' length to show that there is very good agreement between this theoretical prediction and the actual mean distance of separation of stars formed in the outer arms of the spiral galaxy Andromeda M31. Further, the uniform rotation determined from the exact solution relation to equilibrium density and the corresponding rotational velocity for a reference radial distance are consistent with the spectroscopic measurements of Andromeda and the observational data of the spiral Milky Way galaxy.

MSC:

35Q85 PDEs in connection with astronomy and astrophysics
35B36 Pattern formations in context of PDEs
35Q35 PDEs in connection with fluid mechanics
76E07 Rotation in hydrodynamic stability
76E20 Stability and instability of geophysical and astrophysical flows

Keywords:

Andromeda and Milky Way star formation; Jeans' self-gravitational instabilities; rotating adiabatic inviscid gas dynamics; astrophysics

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