Abstract No: PO-22

A modified equation for Roche limit for celestial bodies with a fluid-like structure

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The Roche limit is a concept in astronomy that describes the minimum distance that a celestial body (say satellite) can approach another celestial body (say planet) without being torn into small pieces by tidal forces. This happens when the tidal forces generated on the satellite by the gravitational fields of the planet exceed the self-attractional forces of the satellite. If the planet and satellite are of similar chemical composition, the theoretical Roche limit is about 2.5 times the radius of the planet. Generally, two models have been used for the derivation of Roche limit. If the satellite is assumed to be a solid object, the Roche limit is given by $d = 1.22R_p\left(\frac{\rho_p}{\rho_s}\right)^{\frac{1}{3}}$ and if the physical properties of the satellite are akin to those of a fluid, the expression turns out to be $d = 2.44R_p\left(\frac{\rho_p}{\rho_s}\right)^{\frac{1}{3}}$. Here ρ_p and ρ_s are the densities of the planet and satellite, respectively and R_p is the radius of the planet. These equations have been derived in real physical space for the case where the motion of the satellite and the planet are in the same orbital plane, that is both objects must be in the same equatorial plane. But satellites or asteroids orbit different planes or can enter from another plane like Pluto's orbit. Therefore, a new equation for Roche limit for fluid like satellites, when the equatorial plane of the satellite is tilted to the orbital plane was developed using the tidal generating potential equation and self-gravitational potential equation. This equation takes the form $d = 2.423R_p\left(\frac{\rho_p}{\rho_s}\right)^{\frac{1}{3}}\left(\cos^2\alpha - \frac{1}{3}\right)^{\frac{1}{3}}$, where α is the angle between the orbital plane of the satellite and its equatorial plane.

Keywords: Astrophysics, Axial Tilt, Orbital Plane, Roche Limit, Tidal Potential