Gravitational Stability of Non-radial Modes in Asymmetric Galactic Dark Matter Halo

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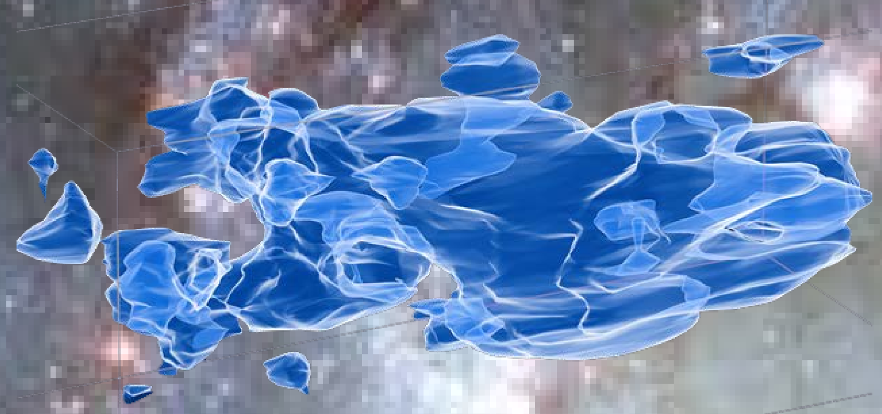


Abstract

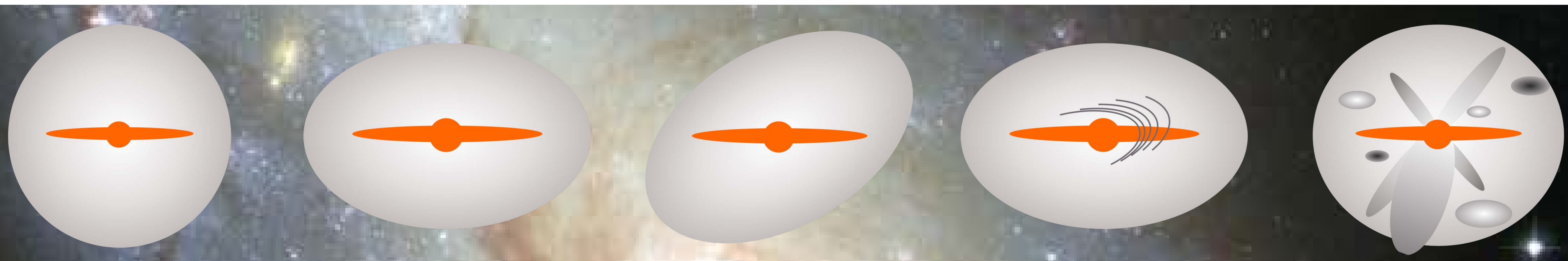
We analyze the Jeans instability of compressible gravitating media in the external asymmetric gravitational potential. The problem can be used to analyze the dynamics of star formation in galaxies, where local gravitational stability is significantly modified by the cold dark matter halo of the galaxy.

For this purpose we expand density and gravitational potential into spherical harmonics and study the linear stability criteria of the non-radial modes. We derive the dispersion equation of the non-radial modes in general case. Assuming marginal gravitational stability of spherically symmetric modes we derive the stability criteria for non-radial modes.

Any observed asymmetry of mass distribution of stars in a galaxy may be used to constraint symmetry (asymmetry) properties of the galactic dark matter halo using the results of our calculations.

Galactic Dark Matter Halo Models

Distribution of the dark matter (DM) in the galaxies is poorly known. DM can be spherically symmetric, ellipsoid, tri-axial, reveal caustic rings or other asymmetric clumpy structures of the unknown origin.



Symmetric Halo | Ellipsoid Halo | Tri-axial Halo | Caustic Rings | Clumpy Structures

Physical Model

Self-gravitating matter under the influence of the external gravitational field:

$$\left[c_s^2\Delta + \omega^2 + 4\pi G\rho_0\right]\rho' = -\rho'\Delta\Phi_{\rm ext} - \nabla\Phi_{\rm ext}\cdot\nabla\rho'$$

Gravitational Potential: *Barionic, Linear perturbation, External (DM):* $\Phi = \Phi_0 + \Phi' + \Phi_{\rm ext}$

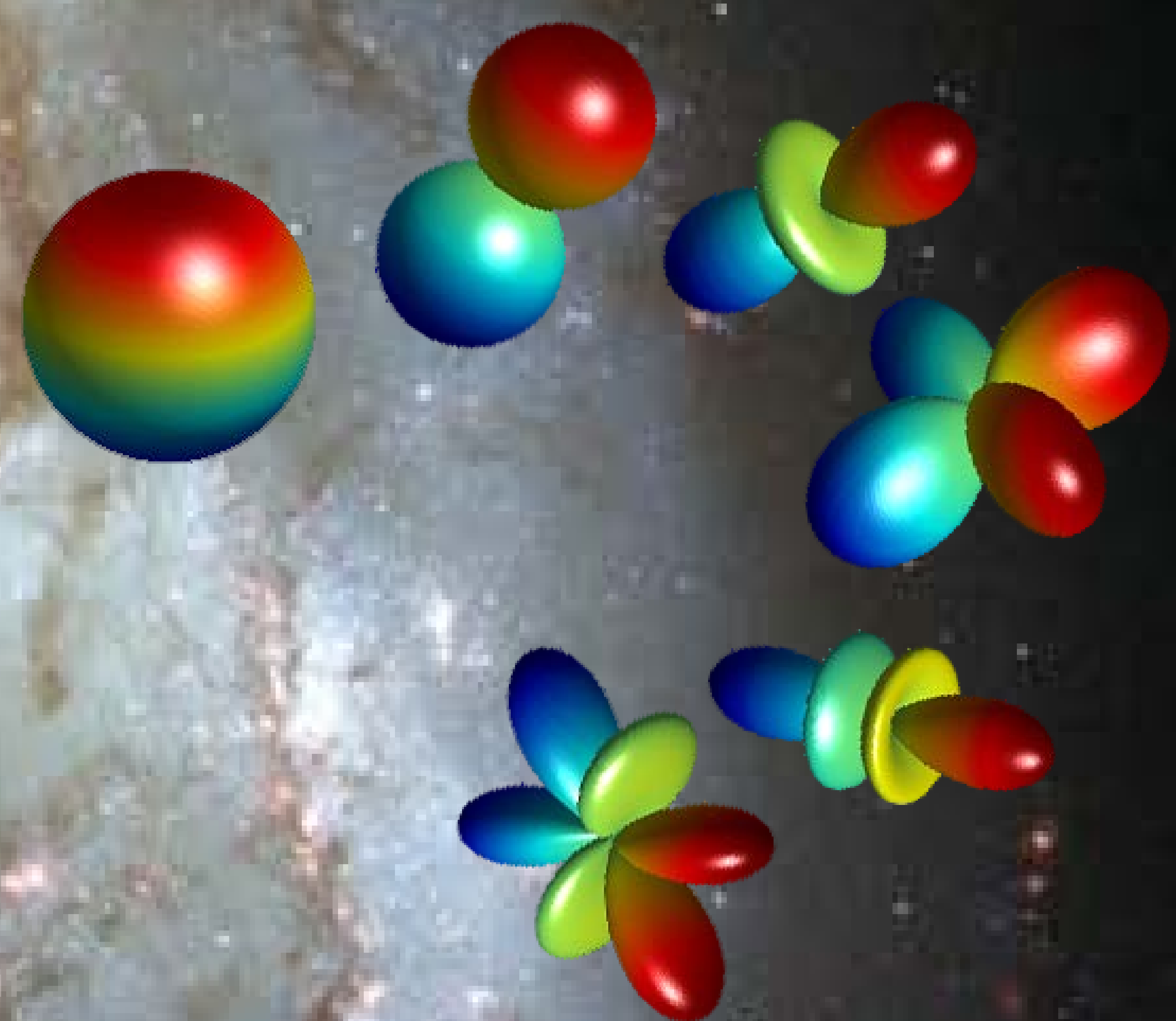
Density Distribution: *Background, Linear perturbation, (DM only in background):* $\rho = \rho_0 + \rho'$

Expansion in Spherical Harmonics: $$\Phi_{\rm ext}(\mathbf{r}) = \sum_{l=0}^{\infty}\sum_{m=-l}^{l}\Phi_{lm}(r)Y_l^m(\phi,\theta)$$

$$\rho_0(\mathbf{r}) = \rho_0(r,\mathbf{\Omega}) = \sum_{l=0}^{\infty}\sum_{m=-l}^{l}\bar{\varrho}_{lm}(r)Y_l^m(\mathbf{\Omega}) \qquad \rho'(\mathbf{r}) = \rho'(r,\phi,\theta) = \sum_{l=0}^{\infty}\sum_{m=-l}^{l}\varrho_{lm}(r)Y_l^m(\phi,\theta)$$

Analytic models of the radial (symmetric) distribution of the DM: $\rho^{\rm DM} = \rho^{\rm DM}(r)$
(Zhao 1996, Merritt 2006);
Analytic models of the radial (symmetric) distribution of luminous matter: $\rho^{\rm b} = \rho^{\rm b}(r)$
(Plummer 1911, King 1962, Seric 1968, Evans 2009);

Assumption: Any asymmetry of baryonic mass distribution (initial mass function, distribution of stars) is due to the asymmetry of external gravitational field (DM).



Results

Dispersion equation describing the gravitational stability of the radial modes (0th order). Assuming neutral gravitational stability on global scale:

$$\frac{c_s^2}{r^2}\frac{d}{dr}\left(r^2\frac{d\varrho_{00}}{dr}\right) + \left[\not{\omega}^2 + 4\pi G\frac{\bar{\rho}_{00}}{\sqrt{4\pi}} + \frac{1}{r^2}\frac{d}{dr}\left(r^2\frac{d}{dr}\left(\frac{\Phi_{00}}{\sqrt{4\pi}}\right)\right)\right]\varrho_{00} + \frac{d}{dr}\left(\frac{\Phi_{00}}{\sqrt{4\pi}}\right)\frac{d\varrho_{00}}{dr} = 0$$

Dispersion equation (reduced due to radial balance) for non-radial modes:

$$\omega^2\varrho_{00} + \sum_{l=1}^{\infty}\sum_{m=-l}^{l}\varrho_{lm}\Psi_{lm} = 0 \qquad \Psi_{lm} = \mathbf{L}(\bar{\rho}_{lm},\rho_{lm},\Phi_{lm})$$

Asymmetry of the star distribution (*l*>*0*): $\varrho_{lm}(r)$

Asymmetry of the external gravitational potential (DM): $\Phi_{lm}(r)$

Jeans instability for non-radial modes: $\omega^2<0$

We interpret asymmetry of the barionic matter as the asymmetry of the Jeans mass distribution. Hence, non-radial dispersion equation can be used to set the symmetry constraints on the dark matter halo using any observed asymmetry in the distribution of the stellar content of the galaxy.

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