CLUSTER DYNAMICS FROM GALAXIES AND ICM - INTRACLUSTER MEDIUM

$\boxed{\text{ICM}}$ Hydrostatic equation for gas $\boxed{\frac{d\Phi}{dr} = -\frac{1}{\rho}\frac{dP}{dr}}$

$$\frac{d\Phi}{dr} = \frac{GM(r)}{r^2} = -\frac{1}{\rho}\frac{dP}{dr} = -\frac{1}{\rho}\frac{d}{dr}\left(\rho \frac{kT}{\mu m_p}\right)$$

Φ potential $\longleftrightarrow$ whole cluster mass

ρ, P density, pressure of ICM

μ mean molecular weight (~ 0.58)

m_p proton mass

$$\frac{GM(r)}{r^2} = -\frac{1}{\rho}\frac{k}{\mu m_p}\left(\rho \frac{dT}{dr} + T\frac{d\rho}{dr}\right)$$

$$M(r) = -\frac{kT}{G\mu m_p} \cdot r \left(\frac{d\ln\rho}{d\ln r} + \frac{d\ln T}{d\ln r}\right)$$

Observationally, the gas distribution is fitted with the ISOTHERMAL β-model (CAVALIERE E FUSCO FEMIANO 76)

3D $\rho_x(r) = \rho_{x,0}\left(1+\left(\frac{r}{r_{c,x}}\right)^2\right)^{-3/2\,\beta_{fit,gas}}$

$\boxed{\beta_{fit\,gas} = \frac{2}{3}}$

2D $\Sigma_x(R) = \Sigma_{0x}\left(1+\left(\frac{R}{r_{cx}}\right)^2\right)^{-3/2\,\beta_{fit,gas}+\frac{1}{2}}$

↳ projected onto the sky!

$\leftarrow \Sigma(R) = \int_{-\infty}^{+\infty}\rho(r)\,dz = 2\int_R^{\infty}\frac{\rho(r)\,dr}{\sqrt{r^2-R^2}}$ $\quad z = \sqrt{r^2 - R^2}$

emissivity $\epsilon_x \propto \rho_x^2 \Rightarrow$

X-ray surface brightness $I_x = I_0\left(1+\left(\frac{R}{r_{cx}}\right)^2\right)^{-3\beta_{fit\,gas}+1/2}$

$\rho_x \longrightarrow r^{-2}$

$\Sigma \xrightarrow{\infty} R^{-1}$

②

$\boxed{\text{GALAXIES}}$

Jean's equation (see Binney and Tremaine)

$$M(r) = -\frac{\sigma_r^2(r)}{G}\left[\frac{d\ln\rho}{d\ln r} + \frac{d\ln\sigma_r^2}{d\ln r} + 2\beta\right]$$

velocity anisotropy parameter !

$$\beta(r) = \left(1 - \frac{\sigma_{\text{tang.}}^2}{\sigma_{\text{radial}}^2}\right)$$

Observationally

3D $\rho(r) = \rho_0\left(1+\left(\frac{r}{r_0}\right)^2\right)^{-3/2\,\beta_{fitgal}}$

2D $\Sigma(r) = \Sigma_0\left(1+\left(\frac{R}{r_0}\right)^2\right)^{-\frac{3}{2}\beta_{fitgal}+\frac{1}{2}}$

= King model modified $\quad \beta_{fitgal} \sim 1$

Hubble modified law

$\rho \xrightarrow{r\to\infty} r^{-3}$

$\Sigma \rightarrow R^{-2}$

$M(r)$ from gas $=$ $M(r)$ from galaxies

Assume that both are isothermal $\frac{dT}{dr}=0 \quad d\frac{\sigma_r^2}{dr}=0$

$$\frac{-kT}{\mu m_p}\frac{d\ln\rho_x}{dr} = -\frac{\sigma_r^2\, d\ln\rho}{dr} - \frac{2\beta\sigma_r^2}{r}$$

$$\frac{\frac{d\ln\rho_x}{dr}}{\frac{d\ln\rho}{dr}+\frac{2\beta}{r}} = \frac{\sigma_r^2}{\frac{kT}{\mu m_p}} \cong \beta_{spec}$$

spectral β

Observations

$\beta_{spec} = \frac{\sigma_{LOS}^2}{\frac{kT}{\mu m_p}}$

$\sigma_r^2 \sim \sigma_{LOS}^2$

For $r \gg r_0$

the ICM and gal profiles $\longrightarrow$

$$\frac{\frac{d\ln\rho_X}{dr}}{\frac{d\ln\rho}{dr}+\frac{2\beta}{r}} \xrightarrow[r \gg r_0]{} \frac{-3\beta_{fit,gas}\cdot\frac{1}{r}}{-3\beta_{fit\,gal}\cdot\frac{1}{r}-\frac{2\beta}{r}} =$$

$$= \frac{\beta_{fit,gas}}{\beta_{fit,gal}-\frac{2}{3}\beta}$$

OTHER POSSIBLE PROBLEM FROM THEORY OF VIOLENT RELAX.

$\beta_{spec} = 1$

THIS IS TRUE FOR CLUSTERS

$$\Rightarrow \quad \beta_{spec} = \frac{\beta_{fit,gas}}{\beta_{fit,gal}-\frac{2}{3}\beta}$$

$\beta \sim 0$

Observations $\quad \beta_{fit\,gas} \sim \frac{2}{3}$

old $\beta_{fit\,gal} \sim 1$

old $\beta_{spec} \gg 1$

$\gg 1 = 2/3 \qquad \beta$ problem !

NOW

in '90 $\quad \beta_{spec}$ with better σ_{Los} measures $\lesssim 1$

$\beta_{fit\,gal} \sim 0{,}8$

$$1 \sim \frac{2/3}{0{,}8} \lesssim 1$$

ok NO LONGER β problem !