Galaxy formation and evolution PAP 318, 5 op, autumn 2020

on Zoom

Lecture 9: Star formation and supernova feedback in galaxies – Additional notes, 06/11/2020

Lecture 9 additional notes I

- Page 4: In the Milky Way the observed star formation rate, SFR~1 $M_{\odot}$/yr, but if gas would be collapsing on the free-fall time the SFR would be SFR~100 $M_{\odot}$/yr, i.e. 100x higher.

- Page 5: Virial theorem without external pressure

$$2K + W = 0, \quad K = \frac{3}{2} N k_b T = \frac{3}{2} M c_S^2, \quad W = -\frac{3}{5} \frac{GM^2}{r_{\rm cl}}$$

- Page 5: Derivation of the Jeans mass:

$$\bar{\rho} = \frac{3M}{4\pi r^3}, \quad M_J = \frac{4\pi}{3} \left(\frac{\lambda_J}{2} \right)^3 \rho, \quad \lambda_J = c_S \left(\frac{\pi}{G\rho} \right)^{1/2}$$

Lecture 9 additional notes II

- Page 5: Derivation of the Jeans mass continued

$$M_J = \frac{\pi}{6} c_S^3 \left(\frac{\pi}{G}\right)^{3/2} \rho^{-1/2}$$

- Page 8: The turbulence in GMCs is supersonic due to the very low gas temperatures, corresponding to low thermal velocities (~0.2 km/s). Thus the supporting velocity is due to turbulence not thermal motions.
- The Mach parameter *M* can enhance overdensities ρ' over the mean density: $$\mathcal{M} = \mathrm{v}_{\mathrm{gas}}/\mathrm{c}_{\mathrm{S}}, \quad \rho' = \mathcal{M}^2 \bar{\rho}$$

Lecture 9 additional notes III

- Page 12: **Adsorption** is the adhesion of atoms, ions or molecules from a gas, liquid or dissolved solid to a surface (in this case the surface of dust grains).
- Page 18: Schmidt-Kennicutt law, star formation controlled by the self-gravity of the gas.

$$\mathrm{SFR} = \epsilon_{\mathrm{SF}} \times \rho_{\mathrm{gas}} / t_{\mathrm{ff}}, \quad t_{\mathrm{ff}} \propto \rho^{-1/2}, \quad \mathrm{SFR} \propto \rho^{1.5}$$

- Page 22: Supernova feedback: (c=NFW halo concentration)

$$E_{\mathrm{fb}} = \epsilon_{\mathrm{SN}} \zeta M_* E_{\mathrm{SN}}, \quad E_{\mathrm{ej}} = \frac{1}{2} M_{\mathrm{ej}} v_{\mathrm{esc}}^2, \quad V_{\mathrm{esc}} \simeq \sqrt{6c} V_{\mathrm{vir}}$$

Lecture 9 additional notes IV

- Page 22: Supernova feedback continued

$$\epsilon_{\rm SN}\zeta M_* E_{\rm SN} = \frac{1}{2}M_{\rm ej}v_{\rm esc}^2, \Rightarrow \frac{M_{\rm ej}}{M_*} \simeq 0.4\epsilon_{\rm SN}\left(\frac{c}{10}\right)^{-1}\left(\frac{v_{\rm vir}}{200\ {\rm km/s}}\right)^{-2}$$

- Page 23: Supernova heating:

$$E_{\rm int} = \frac{3}{2}M_{\rm gas}\frac{k_B T}{\mu m_p}, \qquad T_{\rm vir} = \frac{\mu m_p}{2k_B}V_{\rm vir}^2$$

$$E_{\rm reheat} = \frac{3}{2}M_{\rm gas}\frac{k_B(T_{\rm vir}-T_{\rm init})}{\mu m_p} = \frac{3}{4}M_{\rm gas}V_{\rm vir}^2\left(1-\frac{T_{\rm init}}{T_{\rm vir}}\right)$$

Lecture 9 additional notes V

- Page 23: Supernova heating continued

$$(V_{\rm esc}/V_{\rm vir})^2 \simeq 6c, \quad E_{\rm ej} = \frac{1}{2} M_{\rm ej} V_{\rm esc}^2 = \frac{1}{2} M_{\rm ej} 6c V_{\rm vir}^2$$

- Page 23: Equating the reheating energy to the ejection energy:

$$\frac{M_{\rm gas}}{M_*} \simeq 17\epsilon_{\rm SN} \left(\frac{v_{\rm vir}}{200\ {\rm km/s}} \right)^{-2} \left(1 - \frac{T_{\rm init}}{T_{\rm vir}} \right)^{-1}$$